

PVWMA

# SALT AND NUTRIENT

— MANAGEMENT PLAN —

Final - October 2016



# **Pajaro Valley Water Management Agency Salt and Nutrient Management Plan (SNMP)**

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# TABLE OF CONTENTS

|                                                               |    |
|---------------------------------------------------------------|----|
| Executive Summary .....                                       | ix |
| 1 Introduction.....                                           | 1  |
| 1.1 SNMP Development Objectives.....                          | 1  |
| 1.2 SNMP Stakeholder Process, Roles and Responsibilities..... | 1  |
| 2 Setting.....                                                | 5  |
| 2.1 Pajaro Valley Groundwater Basin (PVGB) Extent.....        | 5  |
| 2.2 PVGB Physical Setting .....                               | 7  |
| 2.2.1 Geologic Structure .....                                | 7  |
| 2.2.2 Climate and Weather .....                               | 7  |
| 2.2.3 Surface Water .....                                     | 9  |
| 2.2.4 Groundwater .....                                       | 9  |
| 3 Groundwater Budget.....                                     | 11 |
| 4 Salt and Nutrient Existing Conditions .....                 | 14 |
| 4.1 Constituents of Concern and Relevant Sources.....         | 14 |
| 4.1.1 Total Dissolved Solids (TDS).....                       | 14 |
| 4.1.2 Chloride (Cl).....                                      | 16 |
| 4.1.3 Nitrate (NO <sub>3</sub> ).....                         | 16 |
| 4.2 Existing Conditions .....                                 | 19 |
| 4.2.1 Groundwater .....                                       | 19 |
| 4.2.2 Surface Water .....                                     | 30 |
| 4.3 Delivered Water Quality .....                             | 35 |
| 5 Salt and Nutrient Loading Analysis.....                     | 37 |
| 5.1 Loading Pathways to Groundwater.....                      | 37 |
| 5.1.1 Seawater Intrusion.....                                 | 37 |
| 5.1.2 Surface Water Infiltration.....                         | 38 |
| 5.1.3 Streamflow Recharge .....                               | 49 |
| 5.2 Salt Loading Potential .....                              | 49 |
| 5.2.1 Seawater Intrusion Loading Potential.....               | 51 |
| 5.2.2 Irrigation Water Salt Loading Potential.....            | 53 |
| 5.2.3 Stream Salt Recharge Potential.....                     | 55 |
| 5.2.4 PVGB Salt Loading Potential .....                       | 57 |
| 5.3 Nitrate Loading Potential .....                           | 58 |
| 5.3.1 Stream Nitrate Recharge Potential .....                 | 60 |
| 5.3.2 Agricultural Nitrogen Loading Potential .....           | 62 |
| 5.3.3 Sewer System Nitrogen Loading Potential .....           | 77 |
| 5.3.4 Septic System Nitrogen Loading Potential .....          | 79 |
| 5.3.5 PVGB Nitrate Loading Potential .....                    | 82 |
| Summary .....                                                 | 84 |

|       |                                                                                     |     |
|-------|-------------------------------------------------------------------------------------|-----|
| 6     | SNMP Goals and Objectives .....                                                     | 85  |
| 6.1   | Goals .....                                                                         | 85  |
| 6.2   | Objectives .....                                                                    | 86  |
| 7     | Assimilative Capacity .....                                                         | 90  |
| 7.1   | Subarea Delineation .....                                                           | 90  |
| 7.2   | Total Dissolved Solids (TDS) .....                                                  | 90  |
| 7.3   | Chloride (Cl) .....                                                                 | 92  |
| 7.4   | Nitrate (NO <sub>3</sub> ) .....                                                    | 93  |
| 8     | Development of Priority Programs .....                                              | 96  |
| 8.1   | Existing Facilities .....                                                           | 96  |
| 8.2   | BMP Conservation Program .....                                                      | 99  |
| 8.2.1 | Partner Coordination and Leveraging of Resources .....                              | 100 |
| 8.2.2 | Recharge Net Metering Pilot Program .....                                           | 101 |
| 8.3   | Projection of Seawater Intrusion and Groundwater Levels .....                       | 101 |
| 9     | Monitoring Plan .....                                                               | 103 |
| 9.1   | Groundwater Monitoring Program .....                                                | 103 |
| 9.2   | Surface Water Monitoring Program .....                                              | 104 |
| 9.3   | Supplemental Water Monitoring Program .....                                         | 105 |
| 9.4   | Soil Monitoring Program .....                                                       | 106 |
| 9.5   | Land Use Monitoring Program .....                                                   | 107 |
| 9.6   | Weather and Climate Monitoring .....                                                | 107 |
| 9.7   | Responsible Party, Sampling Protocols, Quality Assurance, and Quality Control ..... | 108 |
| 9.8   | Salt and Nutrient Monitoring Program .....                                          | 108 |
| 10    | Antidegradation Analysis .....                                                      | 111 |
| 10.1  | Recycled Water Irrigation Projects .....                                            | 111 |
| 10.2  | Recycled Water Irrigation Projects .....                                            | 111 |
| 10.3  | SWRCB Recycled Water Policy Criteria .....                                          | 111 |
| 10.4  | Antidegradation Assessment .....                                                    | 112 |
|       | References .....                                                                    | 114 |
|       | Literature Cited .....                                                              | 114 |
|       | Datasets Used .....                                                                 | 117 |

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## LIST OF TABLES

|      |                                                                                                  |    |
|------|--------------------------------------------------------------------------------------------------|----|
| 1.1  | Stakeholders who attended SNMP workshops                                                         | 2  |
| 1.2  | Summary of stakeholder workshops                                                                 | 3  |
| 1.3  | Chapters provided for stakeholder review                                                         | 4  |
| 3.1  | PVHM groundwater budget summary                                                                  | 13 |
| 4.1  | Summary of relevant federal and state nitrogen standards                                         | 17 |
| 4.2  | Percent of PVGB area within concentration range for TDS data                                     | 21 |
| 4.3  | Percent of PVGB area within concentration range for chloride data                                | 24 |
| 4.4  | Percent of PVGB area within concentration range for nitrate data                                 | 27 |
| 5.1  | Area distribution of groundwater recharge potential from surface infiltration                    | 49 |
| 5.2  | Loading estimates of chloride and TDS resulting from seawater intrusion                          | 51 |
| 5.3  | Acreage summary of seawater intrusion migration potential                                        | 51 |
| 5.4  | Decision matrix to determine categorical irrigation salt loading potential                       | 53 |
| 5.5  | Acreage summary of categorical TDS loading potential                                             | 55 |
| 5.6  | Decision matrix to determine stream infiltration salt loading potential                          | 55 |
| 5.7  | Estimated TDS and chloride loading to groundwater from streams                                   | 57 |
| 5.8  | Decision matrix to determine combined salt loading potential                                     | 58 |
| 5.9  | Acreage summary of combined salt loading potential                                               | 58 |
| 5.10 | Decision matrix to determine stream infiltration nitrate loading potential                       | 60 |
| 5.11 | Estimated nitrate loading to groundwater from streams                                            | 62 |
| 5.12 | 2011/2012 crop use summary and percentage of agricultural land within PVGB                       | 63 |
| 5.13 | Constant values to estimate nitrogen inputs from land use practices                              | 66 |
| 5.14 | Annual relative nitrogen inputs from fertilizer application                                      | 69 |
| 5.15 | Estimated nitrogen inputs from fertilizer application                                            | 69 |
| 5.16 | Estimated range of nitrate concentration in groundwater and nitrate inputs from irrigation water | 70 |
| 5.17 | Annual relative irrigation intensity                                                             | 70 |
| 5.18 | Estimated nitrogen inputs from irrigation                                                        | 71 |
| 5.19 | Estimated range of nitrogen inputs from atmospheric sources                                      | 71 |
| 5.20 | Estimated range of harvested nitrogen for 2012 agricultural yields                               | 72 |
| 5.21 | Estimated range of nitrogen loss from harvested crops                                            | 73 |
| 5.22 | Estimated range of nitrogen loss from surface runoff                                             | 73 |
| 5.23 | Estimated range of nitrogen loss to the atmosphere                                               | 74 |
| 5.24 | Estimated range of nitrogen inputs and outputs as a result of agricultural practices             | 74 |
| 5.25 | Estimated range of nitrogen concentrations in infiltrating water over agricultural lands         | 75 |
| 5.26 | Average soil nitrate-N and nitrate-NO <sub>3</sub> concentrations                                | 76 |
| 5.27 | Annual average nitrate concentrations from PVWMA monitoring wells in the Coastal area            | 77 |
| 5.28 | Range of nitrogen loading by sewer leakage rates                                                 | 79 |
| 5.29 | Range of nitrogen removal and leakage rates by HSG soil types                                    | 82 |
| 5.30 | Low and high nitrogen loading by septic density                                                  | 82 |
| 5.31 | Summary of annual nitrogen leaching to groundwater estimates for Pajaro Valley priority sources  | 83 |

|      |                                                                                                                                        |     |
|------|----------------------------------------------------------------------------------------------------------------------------------------|-----|
| 5.32 | Estimates of potential annual nitrogen load per acre to groundwater                                                                    | 83  |
| 7.1  | Assimilative capacity thresholds and rationale                                                                                         | 90  |
| 7.2  | Assimilative capacity for groundwater TDS                                                                                              | 92  |
| 7.3  | Frequency that average TDS concentrations exceeded assimilative capacity                                                               | 92  |
| 7.4  | Assimilative capacity for groundwater chloride                                                                                         | 93  |
| 7.5  | Frequency that average chloride concentrations exceeded assimilative capacity                                                          | 93  |
| 7.6  | Assimilative capacity for groundwater nitrate                                                                                          | 94  |
| 7.7  | Frequency that average nitrate concentrations exceeded assimilative capacity                                                           | 94  |
| 8.1  | Recommended BMP projects and programs                                                                                                  | 99  |
| 8.2  | Potential additional longer-term projects                                                                                              | 99  |
| 9.1  | PVWMA monitoring program analytes                                                                                                      | 109 |
| 9.2  | Monitoring program summary                                                                                                             | 110 |
| 10.1 | Comparison of delivered water quality to the existing groundwater conditions within the DWZ, the coastal area and to the regional WQOs | 112 |
| 10.2 | Recycled water project compliance with Resolution NO. 68-16                                                                            | 113 |

## LIST OF FIGURES

|      |                                                                                              |    |
|------|----------------------------------------------------------------------------------------------|----|
| 2.1  | SNMP project area, location and geography                                                    | 6  |
| 2.2  | Precip frequency analysis – Watsonville Water Works                                          | 8  |
| 2.3  | PVGB groundwater contours                                                                    | 10 |
| 3.1  | PVWMA boundary & PVHM boundary                                                               | 12 |
| 4.1  | Salt cycling on irrigated land                                                               | 14 |
| 4.2  | Relevant components of the nitrogen cycle                                                    | 18 |
| 4.3  | Location of 310 groundwater wells sampled for nitrate, chloride or TDS                       | 20 |
| 4.4  | Interpolated average groundwater TDS concentrations                                          | 22 |
| 4.5  | Interpolated maximum groundwater TDS concentrations                                          | 23 |
| 4.6  | Interpolated average groundwater chloride concentrations                                     | 25 |
| 4.7  | Interpolated maximum groundwater chloride concentrations                                     | 26 |
| 4.8  | Interpolated average groundwater nitrate concentrations                                      | 28 |
| 4.9  | Interpolated maximum groundwater nitrate concentrations                                      | 29 |
| 4.10 | PVWMA surface water quality monitoring site locations                                        | 31 |
| 4.11 | Quarterly average TDS concentrations                                                         | 32 |
| 4.12 | Quarterly average chloride concentrations                                                    | 33 |
| 4.13 | Quarterly average nitrate concentrations                                                     | 34 |
| 4.14 | Water supply facilities & seawater intrusion                                                 | 36 |
| 5.1  | Seawater intrusion within the Pajaro Valley                                                  | 39 |
| 5.2  | Relative soil water holding capacity                                                         | 41 |
| 5.3  | Recharge zones within the PVWMA boundaries                                                   | 43 |
| 5.4  | Recharge zones designated by Barry Hecht                                                     | 44 |
| 5.5  | Groundwater pollutant potential variables                                                    | 45 |
| 5.6  | Groundwater recharge potential                                                               | 46 |
| 5.7  | Inputs to groundwater relative recharge potential map                                        | 47 |
| 5.8  | Relative groundwater recharge potential for PVWMA                                            | 48 |
| 5.9  | Relative stream-bed vertical conductivity for major PVWMA streams                            | 50 |
| 5.10 | Potential seawater intrusion                                                                 | 52 |
| 5.11 | Categorical irrigation salt loading potential to groundwater within PVWMA                    | 54 |
| 5.12 | Categorical surface water recharge salt loading potential                                    | 56 |
| 5.13 | Categorical potential of salt loading to groundwater                                         | 59 |
| 5.14 | Categorical surface water recharge salt loading potential                                    | 61 |
| 5.15 | Agricultural land use, 2010-2012                                                             | 64 |
| 5.16 | Agriculture crop distribution based on assigned crop type designations                       | 65 |
| 5.17 | Modeled nitrogen loading to groundwater using inputs and outputs from agricultural practices | 75 |

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|      |                                                                                                 |     |
|------|-------------------------------------------------------------------------------------------------|-----|
| 5.18 | Existing sewer lines                                                                            | 78  |
| 5.19 | Sanitary sewer overflow incident map                                                            | 80  |
| 5.20 | Location of existing septic systems and septic system density within PVWMA boundary             | 81  |
| 5.21 | Total potential nitrogen loading to groundwater from surface and stream infiltration            | 83  |
| 6.1  | Projected recycled water production through 2020                                                | 87  |
| 7.1  | Assimilative capacity for two zones within PVGB                                                 | 91  |
| 7.2  | Average concentration values for each constituent                                               | 95  |
| 8.1  | Harkins Slough Facility Operations with recharge and recovery                                   | 97  |
| 8.2  | Delivered water and groundwater usage trends in the delivered water zone                        | 98  |
| 8.3  | Example results comparing baseline and selected alternative simulation for Upper Aromas Aquifer | 102 |

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## LIST OF ACRONYMS AND ABBREVIATIONS

|                 |                                                      |
|-----------------|------------------------------------------------------|
| ACR             | Agricultural Commissioner's Reports                  |
| ac              | acre                                                 |
| AF              | acre-feet                                            |
| AFY             | acre-feet per year                                   |
| BMP             | <a href="#">PVWMA Basin Management Plan</a>          |
| CCRWQCB         | Central Coast Regional Water Quality Control Board   |
| CDS             | Coastal Distribution System                          |
| CFS             | cubic feet per second                                |
| Cl              | chloride                                             |
| cm              | centimeters                                          |
| CWD             | Community Water Dialogue                             |
| DWZ             | Delivered Water Zone                                 |
| EPA             | US Environmental Protection Agency                   |
| g               | grams                                                |
| GIS             | Geographic Information Systems                       |
| HS-ASR          | Harkins Slough Aquifer Storage and Recovery System   |
| IDW             | Inverse Distance Weighted                            |
| IRWM            | Integrated Regional Water Management                 |
| lbs             | pounds                                               |
| MAR             | Managed Aquifer Recharge                             |
| MCWRA           | Monterey County Water Resources Agency               |
| mg/L            | milligram per liter                                  |
| N               | Nitrogen                                             |
| NO <sub>3</sub> | Nitrate                                              |
| NRCS            | Natural Resources Conservation Service               |
| PCSD            | Pajaro County Sanitation District                    |
| PVGB            | Pajaro Valley Groundwater Basin                      |
| PVHM            | Pajaro Valley Hydrologic Model                       |
| PVWMA           | Pajaro Valley Water Management Agency                |
| RCDSCC          | Resources Conservation District of Santa Cruz County |
| t               | short tons                                           |
| TDS             | total dissolved solids                               |
| SBCWD           | San Benito County Water District                     |
| SCVWD           | Santa Clara Valley Water District                    |
| SNMP            | Salt and Nutrient Management Plan                    |
| SSO             | Sanitary Sewer Overflow                              |
| SWRCB           | State Water Resources Control Board                  |
| UCSC            | University of California Santa Cruz                  |
| USDA            | US Department of Agriculture                         |
| USGS            | US Geological Survey                                 |
| WQO             | Water Quality Objectives                             |
| WWTP            | Watsonville Wastewater Treatment Plant               |
| WY              | Water Year                                           |
| Yr              | year                                                 |

# EXECUTIVE SUMMARY

## INTRODUCTION AND DEVELOPMENT OBJECTIVES

The Pajaro Valley Water Management Agency (PVWMA or Agency) has developed a Salt and Nutrient Management Plan (SNMP) to meet the requirements of the Recycled Water Policy, which was adopted by the State Water Resources Control Board (SWRCB) in 2009. The purpose of the plan is to ensure attainment of water quality objectives for protection of beneficial water uses and guide management of salts, nutrients, and other significant chemical compounds within the groundwater basins of the State. The Recycled Water Policy states that development of the SNMP shall be a stakeholder driven process. To this end, PVWMA has hosted four stakeholder workshops since 2012 to review draft products and solicit input. Over 20 stakeholders participated in this effort, representing agriculture, recycled water, wastewater, non-profits, local government agencies, and community members. The content and objectives of this SNMP were developed to align with the PVWMA Basin Management Plan (BMP) Update (PVWMA, 2014), which provides strategy to achieve sustainable groundwater resources through the elimination of groundwater overdraft and seawater intrusion. The approach and content are generally consistent with SNMPS recently developed by the San Benito County and the Santa Clara Valley water districts for neighboring groundwater basins.

## SETTING

This SNMP is focused on the 113 square miles within the Pajaro Valley Groundwater Basin (PVGB) portion of the PVWMA statutory boundary, which includes portions of Santa Cruz, Monterey, and San Benito Counties (Figure 2.1). Defined by both physical and jurisdictional constraints, the PVGB is bounded by the coast to the west and the San Andreas Fault to the east, and for the purposes of this SNMP, by the PVWMA statutory boundary to the north and south. The groundwater basin is comprised of multiple interconnected hydrologic units that together define the relationship between recharge, groundwater extraction via pumping and the associated changes in groundwater levels (PVWMA 2014). The PVGB behaves similar to a closed basin under recent and current groundwater conditions. Groundwater flow from most directions is toward the center of the valley, where water levels are lowest (Figure 2.3), due to depressed groundwater levels within the center of the valley, an impact of long-term groundwater overdraft.

## GROUNDWATER BUDGET

The PVWMA collaborated with United States Geological Survey (USGS) to develop a robust hydrologic model of the PVGB known as the Pajaro Valley Hydrologic Model (PVHM). The PVHM was used to simulate the use and movement of water within the PVGB from 2005 to 2009 to determine a water budget and to better understand the connections between groundwater, surface water, and salt and nutrient loading (Figure 3.1 and Table 3.1). Simulated results from the model include quantitative estimates of the annual inflows, outflows and change in storage of the PVGB. In order of relative contribution, the average annual inflows to the groundwater basin are estimated to be direct surface water infiltration (63% of total inflows), streamflow infiltration (30% of total inflows), and landward underflow (7% of total inflows). The largest annual outflow is due to groundwater extraction for agricultural purposes (72% of total outflows). The model mass balance results support water level monitoring data that suggest that the PVGB is currently in a state of overdraft, with an estimated average annual deficit of 9,800 acre-feet per year (AFY) over the simulation period of water years

2005-2009. Long-term groundwater overdraft has resulted in groundwater storage depletion, the lowering of groundwater levels, and seawater intrusion, which are all threats to beneficial water uses. The PVWMA has developed a Basin Management Plan (PVWMA, 2014) that provides a suite of projects and programs designed to balance the basin and halt seawater intrusion. The PVHM was used as a tool during the planning process to identify the magnitude of the deficit in the PVGB water budget (approximately 12,100 AFY) and to evaluate the effectiveness of the water management scenarios proposed in the BMP.

## **EXISTING GROUNDWATER AND SURFACE WATER QUALITY CONDITIONS**

The three priority constituents selected to document and communicate groundwater and surface water quality conditions are total dissolved solids (TDS), chloride (Cl), and nitrate ( $\text{NO}_3$ ). TDS is used as a proxy for the bulk salt content of water, chloride is a good indicator for seawater intrusion, and nitrate, which is highly mobile in water, is used as the proxy for nutrients species including nitrogen and phosphorous. The Central Coast Water Quality Basin Plan has a median groundwater quality objective for TDS and chloride of 1000 mg/L and 150 mg/L, respectively (Table 4.1). The EPA drinking water standard for nitrate- $\text{NO}_3$  is 45 mg/L due to human health concerns when the threshold is exceeded (Table 4.1).

An assessment of existing groundwater conditions for these constituents was completed using the extensive PVWMA groundwater monitoring dataset. Groundwater sample results from 2002 to 2011 were compiled from more than 300 wells located throughout the PVGB. A spatially weighted analysis of these data indicates the average PVGB groundwater concentration of TDS, chloride, and nitrate- $\text{NO}_3$  was 527 mg/L, 83 mg/L, 28 mg/L, respectively during the last decade (Figures 4.4, 4.6, and 4.8). Relatively elevated TDS and chloride concentrations exist along the coast as result of seawater intrusion, and along a reach of the Pajaro River located upstream of Murphy Crossing where the streamflow infiltration rates tend to be very high.

PVWMA has monitored surface water quality at sites throughout the basin on a monthly to quarterly frequency since 1994 (Figure 2.10). Salt and nutrient concentrations in surface waters are seasonally variable with lower concentrations during winter months when flows are higher. Summer surface water flows (base flow) tend to have higher concentrations. Analysis of average surface water concentrations by season revealed that sites along the coast and on the Pajaro River downstream of Chittenden Gap have higher average salt content (TDS >450 mg/L) during base flow conditions (Figures 4.11 and 4.12). Approximately 25% of sites have nitrate- $\text{NO}_3$  concentrations that exceed 45 mg/L during summer months (Figure 4.13).

Water delivered via the Coastal Distribution System (CDS) began in 2009 and is used for agricultural irrigation supply to reduce the amount of annual groundwater extraction by growers in the Delivered Water Zone (DWZ; Figure 4.14). The water delivered through the PVWMA water supply facilities is sampled extensively. Within the DWZ, the average concentration for each constituent of concern is 612 mg/L TDS, 104 mg/L chloride, and 27 mg/L nitrate- $\text{NO}_3$ .

## **SALT AND NUTRIENT LOADING ANALYSIS**

A loading analysis was conducted to identify the primary sources of salts and nutrients and estimate their relative loading to the groundwater basin. The three primary pathways for salts and nutrients to enter groundwater are surface water infiltration (such as applied irrigation water), streamflow infiltration, and seawater intrusion. Total salt loading potential was determined by intersecting surface

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infiltration potential and known areas of seawater intrusion. A quantitative nitrogen loading analysis was conducted using agricultural data specific to the Pajaro Valley. A similar approach had previously been applied in two neighboring basins that were also highly agricultural by Viers *et al.* (2012).

A basin wide groundwater recharge potential map (Figure 5.8) was modified from work completed by Russo *et al.* (2014) by integrating a plethora of existing data sources that spatially represent the relative potential of groundwater recharge via surface infiltration, the largest input to the PVGB. The progress of seawater intrusion within the PVGB has been tracked since the mid-1900s by PVWMA and others (Bul. 5, 1953). Many of the coastal wells monitored have demonstrated large increases in chloride concentrations over the past six decades. The total salt loading potential to groundwater in the Basin as a result of seawater intrusion, irrigation water, and stream infiltration, is highest along the coast where the seawater intrusion potential is high (Figure 5.13). Areas of moderate loading potential are located in the upper Pajaro River where surface water salt concentrations and recharge potential is elevated.

A mass balance approach was used to estimate nitrate-NO<sub>3</sub> leaching potential to groundwater as a result of agricultural practices. The approach follows that of Viers *et al.* (2012) for the neighboring Salinas Valley and is based on the growth and harvest of specific crop types, fertilizer application rates, and irrigation practices. Estimates of atmospheric inputs and outputs as well as surface runoff are also included in the analysis. The total nitrogen loading potential to groundwater in the PVGB as a result of stream infiltration and surface infiltration via agricultural practices, sewer, and septic systems, is highest in agricultural areas (Figure 5.21 and Table 5.31). A comparison of nitrogen sources found that agricultural land uses contributed 91% of the potential amount of nitrogen load with relatively minor contributions from septic, streams, and sewer. The basin wide calculation of nitrogen load per acre ranges from 26 lbs N/ac/yr to 71 lbs N/ac/yr. Agricultural practices located in relatively high recharge zones are likely to contribute a greater proportion of the agriculturally derived nitrogen load to groundwater.

## **SNMP GOALS AND OBJECTIVES**

Goals and objectives provide a target from which to assess current and projected changes in loading sources, groundwater, and surface water degradation. In February 2009, the SWRCB adopted goals to significantly increase recycled water use, storm water reuse, and water conservation over the next two decades. To meet these goals, the 2014 BMP Update provides the foundational strategy to balance the basin, eliminate groundwater overdraft, and stop seawater intrusion (the largest source of salt to the groundwater basin). Programs identified in the 2014 BMP Update will optimize production of recycled water within the PVGB, put local surface water supplies to beneficial use, and implement robust irrigation efficiency programs. These programs will result in decreasing groundwater production within the overdrafted PVGB, and have a beneficial impact on groundwater quality, particularly through the managed recharge of high quality surface water.

The SNMP goals and objectives stated in Chapter 6.1 build off the adopted BMP. With the continued implementation of the BMP, groundwater production is decreasing because of increased supplemental water supply use and improved irrigation efficiency resulting from water conservation programs. Improved irrigation efficiency and nutrient management practices lead to a reduction in salt and nutrient loading from irrigation practices. The comparison between existing conditions documented in this report and future conditions will provide a measure of the success of the SNMP and BMP Update.

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## ASSIMILATIVE CAPACITY

The assimilative capacity of the PVGB to receive salts and nutrients without damage to aquatic life or to humans that utilize the water was determined by delineating the PVGB in two sub-basins and comparing existing average concentrations of TDS, chloride, and nitrate-NO<sub>3</sub> to relevant water quality objectives. The sub-basin boundary was defined by the relative potential for seawater intrusion (Figure 7.1). Objectives for nearby basins and regional water quality standards were used to define assimilative capacity thresholds. The median water quality objective defined by the Central Coast Regional Water Quality Control Board (CCRWQCB) Basin Plan in Table 3-8 "Median Ground Water Objectives" for TDS and chloride is 1000 mg/L and 150 mg/L, respectively (CCRWQCB, 2016). The EPA national drinking water standard for nitrate-NO<sub>3</sub> is 45 mg/L (US EPA, 2009). The amount of remaining assimilative capacity was evaluated for two sub-basins within the PVGB for each constituent of concern. While some individual monitoring wells exceeded the assimilative capacity threshold, nearly all areas met water quality objectives for assimilative capacity (Figure 7.3). The area that did not meet with water quality objectives was the coastal sub-basin which exceeded assimilative capacity for chloride. A USGS team age dated the water from the wells with very high chloride concentrations indicated the water in some cases was very old, up to 24,900 years (USGS, 2003).

## DEVELOPMENT OF PRIORITY PROGRAMS

The Basin Management Plan (BMP) describes the water resources management approach to balancing the groundwater basin and stopping seawater intrusion, and priority programs within PVGB are detailed extensively in the 2014 Basin Management Plan ([BMP Update](#)). By design, the implementation of the BMP will improve the quality of groundwater within the basin and meet the objectives of the SNMP. The Agency is attempting to meet the 12,100 AFY deficit by establishing conservation programs to use existing supplies more efficiently, optimizing existing supply facilities, and constructing new water supply facilities. The BMP is revisited every 5 to 10 years to determine if the projects and programs remain the most effective way to achieve goals and adaptively manage based on current basin conditions.

Operational facilities constructed by PVWMA include the Harkins Slough managed aquifer recharge and recovery facility, the Watsonville Area Water Recycling Facility, the Coastal Distribution System water conveyance pipeline, supplemental wells, and a connection to the City of Watsonville's water system. The Harkins Slough Facility has recharged nearly 8,000 AF of surface water since its implementation, and recovery wells have provided 2,500 AF of supplemental irrigation supply to replace groundwater pumping. The Watsonville Area Water Recycling Facility has produced over 16,200 AF of disinfected, tertiary treated, Title 22 compliant recycled water since 2009. Use of recycled water is expected to increase to 4,000 AFY by 2020.

The BMP Conservation program intends to reduce water use by 5,000 AFY by facilitating coordination of conservation related activities conducted by partner agencies. The program provides financial assistance to participating growers to maximize grower adoption and efficient water use practices. PVWMA also facilitates conservation by working with partner agencies including the Resource Conservation Districts, the Natural Resources Conservation Service (NRCS), the U.C. Ag Extension, and other local groups to achieve conservation goals. The PVWMA board of directors approved a 5-year Recharge Net Metering (ReNeM) pilot program in March of 2016. This effort in collaboration with University of California Santa Cruz (UCSC), and the RCD-SCC will support BMP goals by working to collect and recharge stormwater runoff in strategic locations within the PVGB. The program provides

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financial incentives to landowners to develop recharge basins in locations that are highly connected to the aquifer. The goal of this effort will be to recharge 1,000 AFY through 8-10 projects, providing an additional source of high quality stormwater runoff.

## **MONITORING PLAN**

The Recycled Water Policy states that the SNMP should include a monitoring program that consists of a network of monitoring locations adequate to determine whether the concentrations of salts and nutrients are consistent with applicable water quality objectives. PVWMA maintains robust groundwater, surface water, and supplemental water (i.e. recycled water and water recovered from managed aquifer recharge) monitoring programs. PVWMA also supports a soil monitoring program in the DWZ and land use monitoring program to survey agricultural land use. Tracking changes to water quality and quantity, land use, and soils through time helps to inform water managers of the state of the basin. Several elements of the monitoring program have been in place over twenty years which have facilitated the creation of an extensive and valuable PVWMA water quality database that can be used to address a number of water quality questions and trends in the Basin. Monitoring data collected as a result of these programs were used to generate a number of the analyses, figures and tables included throughout this SNMP. The monitoring program is in a constant state of change with new wells being added to improve the network as funding and time allow.

## **ANTIDEGRADATION**

The Recycled Water Policy requires that each SNMP include an antidegradation analysis that demonstrates that projects comply with Resolution 68-16. In order to comply with Resolution 68-16, a single recycled water project may use less than 10% of the available assimilative capacity (and multiple recycled water projects may use less than 20% of the available assimilative capacity) until such time as an SNMP is adopted. This SNMP demonstrates that the Watsonville Recycled Water Treatment Facility, the only recycled water use in this plan, does not reduce the existing assimilative capacity. Water delivered in the DWZ has lower concentrations for each of the constituents compared to existing groundwater within the DWZ and the coastal area (Table 10.1). The delivered water concentrations of 612 mg/L TDS, 104 mg/L chloride, and 27 mg/L nitrate-NO<sub>3</sub> also fall beneath the assimilative capacity threshold defined by the water quality objectives. The Watsonville Recycled Water Treatment Facility that supplies recycled water to the DWZ meets the criteria of each component of Resolution N0. 68-16 (Table 10.2) and does not take up additional assimilative capacity. In addition, the DWZ is impacted by seawater intrusion, which reduces the beneficial uses of groundwater in this area.

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# 1 INTRODUCTION

The California SWRCB adopted a Recycled Water Policy in 2009 that requires every groundwater basin or sub-basin in California to develop SNMPs to manage salts, nutrients, and other significant chemical compounds. SNMPs are intended to help streamline permitting of new recycled water projects while ensuring attainment of water quality objectives and protection of beneficial uses. As part of the Integrated Regional Water Management (IRWM) Plan, SNMPs will be completed for the entire Pajaro River Watershed, which encompasses the jurisdictions of three water districts: Santa Clara Valley Water District (SCVWD), San Benito County Water District (SBCWD), and PVWMA. SCVWD is developing the SNMP for the Llagas sub-basin, SBCWD is developing the SNMP for the Bolsa, Hollister, San Juan Bautista Area, and Tres Pinos sub-basins, and PVWMA is developing the SNMP for the PVGB. Stakeholder involvement and input is a critical component of each SNMP.

## 1.1 SNMP Development Objectives

The development of the SNMP had a number of objectives:

1. Maintain consistency with, and leverage complementary water management plans completed either by PVWMA or within the Pajaro River Watershed to the extent practical, including, but not limited to, the 2014 PVWMA Basin Management Plan Update and SNMPs under development by SBCWD and SCVWD on the upper portions of the Pajaro River Watershed.
2. Consider and incorporate stakeholder input into the SNMP.
3. Provide content and recommendations that are consistent with regulatory requirements to prevent groundwater quality degradation and protect groundwater beneficial uses for Agricultural Water Supply (AGR), Municipal and Domestic Supply (MUN) and Industrial Service Supply (IND).
4. Gain general consensus by participating Pajaro Valley stakeholders.
5. Gain acceptance by the Pajaro Valley Water Management Agency Board of Directors.
6. Gain acceptance by the Central Coast Regional Water Quality Control Board (CCRWQB).

## 1.2 SNMP Stakeholder Process, Roles and Responsibilities

The PVWMA utilized a stakeholder driven process to develop the Pajaro Valley SNMP. During four stakeholder workshops held between July 2012 and June 2016, stakeholders served the following roles: provided input to the SNMP development process, and reviewed and commented on individual components of the SNMP. Specifically, stakeholders were asked to review the methods and assumptions used to determine: 1) existing groundwater conditions, 2) the approach to both salt and nutrient loading analyses, 3) the approach to evaluating assimilative capacity and anti-degradation, and 4) the development of goals and objectives. Following the completion of the Public Review Draft SNMP in May 2016, stakeholders convened to review the complete document and provide comments.

Staff identified potential stakeholders from a combination of existing stakeholder lists, such as the PVWMA's Ad Hoc Basin Management Planning Stakeholder Committee, and supplemented the list with additional interested parties. PVWMA notified stakeholders of the SNMP development process by noticing the first meeting in the local newspapers, on the PVWMA's website, by email, and at other publically noticed meetings such as the Board of Directors meeting. PVWMA created a web page dedicated to the SNMP development process on its website ([pvwater.org](http://pvwater.org)). Staff posted all relevant

materials, including agendas, minutes, presentations, and drafts of the report to that web page. Stakeholders invited to attend SNMP workshops included representatives from agricultural interests, municipalities, water agencies, small water mutuals, rural residents, regulatory staff, other agencies such as the Resource Conservation Districts and the Natural Resources Conservation Service, private companies, and the public. Table 1.1 lists the representatives that attended SNMP stakeholder workshops, as well as their responsibilities to the SNMP. As new stakeholders attended SNMP meetings, staff added them to the distribution list.

**Table 1.1:** Stakeholders who attended SNMP Workshops.

| Affiliation                                         | SNMP Responsibility                                                                                               | Representative   |
|-----------------------------------------------------|-------------------------------------------------------------------------------------------------------------------|------------------|
| 2NDNATURE                                           | Technical Development,<br>Lead Report Preparer                                                                    | Brian Spear      |
|                                                     |                                                                                                                   | Michael Founds   |
|                                                     |                                                                                                                   | Maggie Mathias   |
|                                                     |                                                                                                                   | Nicole Beck      |
| Consulting Agronomist                               | Technical Development                                                                                             | Belinda Platts   |
| Central Coast Agricultural Water Quality Coalition  | Review and Comment                                                                                                | Erin McCarthy    |
| Central Coast Regional Water Quality Control Board  | Enforce Recycled Water Policy,<br>Implement Ag Order,<br>Consider Report Approval                                 | Cecile DeMartini |
|                                                     |                                                                                                                   | Matt Keelign     |
| Central Coast Water Quality Preservation, Inc.      | Review and Comment                                                                                                | Kirk Schmidt     |
|                                                     |                                                                                                                   | Sarah Lopez      |
| City of Watsonville                                 | Review and Comment,<br>Manage City Wastewater Treatment Plant                                                     | Jim Crowley      |
|                                                     |                                                                                                                   | Robert Ketley    |
| Community Member                                    | Review and Comment                                                                                                | Margie Kay       |
|                                                     |                                                                                                                   | Steve Fessler    |
| Driscolls                                           | Review and Comment                                                                                                | Sam Cooley       |
|                                                     |                                                                                                                   | Emily Paddock    |
| Environmental Incentives                            | Facilitate Workshops                                                                                              | Chad Praul       |
| Friends of Buena Vista                              | Review and Comment                                                                                                | Joe Pendry       |
| Strategic Marketing                                 | SNMP Development Public Outreach                                                                                  | Steve Stagnaro   |
| PVWMA Director                                      | Set PVWMA Policy,<br>Consider SNMP Report Approval                                                                | Amy Newell       |
|                                                     |                                                                                                                   | Rosemarie Imazio |
| PVWMA Staff                                         | Implement Board Policy,<br>Manage the PVGB,<br>Deliver Recycled Water,<br>Prepare Report,<br>Technical Assistance | Mary Bannister   |
|                                                     |                                                                                                                   | Brian Lockwood   |
|                                                     |                                                                                                                   | Casey Meusel     |
| Resource Conservation District of Santa Cruz County | Review and Comment                                                                                                | Lisa Lurie       |
|                                                     |                                                                                                                   | Sacha Lozano     |
|                                                     |                                                                                                                   | Gerry Spinelli   |
| Santa Cruz County                                   | Manage Septic Systems and Well Applications,<br>Review and Comment                                                | John Ricker      |
|                                                     |                                                                                                                   | Sierra Ryan      |
| Watsonville Wetlands Watch                          | Review and Comment                                                                                                | Donna Bradford   |
|                                                     |                                                                                                                   | Jonathan Pilch   |

PVWMA hosted four stakeholder workshops between July 2012 and June 2016. Workshop were between two and four hours long and generally consisted of a presentation with pauses throughout to receive input from stakeholders concerning key items, assumptions, methods, etc. Staff posted workshop agendas, minutes, and presentations to the PVWMA's SNMP webpage following each meeting. Also posted on the web page are links to the State Water Resources Control Board's Recycled Water Policy, SNMP Required Elements, and the SNMP plan itself. Table 1.2 provides a summary of workshop dates and topics discussed.

**Table 1.2: Summary of Stakeholder Workshops.**

| Meeting                                                                                                                                                                                                                                                                                                                                                                                                     |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>SNMP Workshop 1, July 17, 2012, 10:00 AM to Noon</b> <ul style="list-style-type: none"> <li>- Introduction to Salt &amp; Nutrient Management Plans</li> <li>- Stakeholder Roles</li> <li>- Development Schedule</li> <li>- Technical Overview</li> <li>- Short &amp; Long-term Goals</li> <li>- Engaging Additional Stakeholders</li> <li>- Next Steps</li> </ul>                                        |
| <b>SNMP Workshop 2, March 28, 2013, 9:00 AM to Noon</b> <ul style="list-style-type: none"> <li>- SNMP Plan Overview</li> <li>- Existing Groundwater Conditions</li> <li>- Draft Loading Analysis Approach</li> <li>- Nutrient Loading Analysis</li> <li>- Salt Loading Analysis</li> <li>- Assimilative Capacity Approach</li> <li>- SNMP Objective Development</li> <li>- Next Steps</li> </ul>            |
| <b>SNMP Workshop 3, July 25, 2015, 10:00 AM to 1:00 PM</b> <ul style="list-style-type: none"> <li>- PVWMA Update</li> <li>- SNMP Overview</li> <li>- Review Findings of Existing Groundwater Conditions</li> <li>- Review Findings of Assimilative Capacity</li> <li>- Draft Loading Analysis Approach</li> <li>- Goal &amp; Objectives</li> <li>- Anti-degradation Policy</li> <li>- Next Steps</li> </ul> |
| <b>SNMP Workshop 4, June 10, 2016, 10:00 AM to Noon</b> <ul style="list-style-type: none"> <li>- PVWMA Update</li> <li>- SNMP Overview</li> <li>- Discuss Public Review Draft SNMP</li> <li>- Receive Stakeholder Comments</li> <li>- Next Steps</li> </ul>                                                                                                                                                 |

In order to facilitate stakeholder input, staff and consultants provided a series of draft documents at critical milestones, allowing for an incremental development approach to the final PVWMA SNMP. Table 1.3 lists the chapters included in the SNMP. For each chapter, the development team delivered all text and figures as well as a comment form to stakeholders, established a minimum 2-week review period, and provide responses to all comments along with incorporated changes to the document. During stakeholder workshops, the technical team presented the methodology and analyses and stakeholders discussed in detail and provided feedback.

**Table 1.3:** *Chapters provided for stakeholder review are listed in order below.*

| SNMP Chapters                                    |
|--------------------------------------------------|
| Chapter 1. Introduction                          |
| Chapter 2. Setting                               |
| Chapter 3. Groundwater Budget                    |
| Chapter 4. Salt and Nutrient Existing Conditions |
| Chapter 5. Salt and Nutrient Loading Analysis    |
| Chapter 6. SNMP Goals and Objectives             |
| Chapter 7. Assimilative Capacity                 |
| Chapter 8. Development of Priority Programs      |
| Chapter 9. Monitoring Plan                       |
| Chapter 10. Antidegradation Analysis             |

## 2 SETTING

The SNMP focuses on the approximately 113 square mile area within the PVWMA's service area, that is defined as the PVGB. This chapter details the physical and jurisdictional constraints of the PVGB as well as provides a brief overview of its physical setting. In 2014, the PVWMA completed and adopted the BMP Update that includes a detailed summary of the state of the basin (Chapter 2, PVWMA 2014), detailing the hydrogeologic setting, precipitation patterns, historic and current land use data, and information about water supplies and usage. The PVWMA continues to compile and manage a breadth of diverse physical and chemical datasets that were utilized extensively to develop this SNMP.

### 2.1 Pajaro Valley Groundwater Basin (PVGB) Extent

For the purpose of clarity, it is important that several terms defining relevant boundaries be defined at this point in the report. The boundaries include the following: 1) the PVWMA statutory boundary, or service area; 2) the Pajaro Valley Basin as defined by the California Department of Water Resources ([Bulletin 118](#)), and 3) the Pajaro Valley Groundwater Basin (PVGB), which is being defined specifically for the purposes of this SNMP. The statutory boundary of the PVWMA is located in the lower Pajaro River Watershed, below Chittenden Gap, and includes portions of Santa Cruz, Monterey, and San Benito Counties (Figure 2.1). The California Department of Water Resources (DWR) define the Pajaro Valley Basin in detail in Bulletin 118, however in simple terms the basin is bounded by the ocean to the west, the San Andreas Fault to the east and extends beyond the PVWMA statutory in both the north-west and south-east directions. A basin boundary modification request as allowed by the Sustainable Groundwater Management Act has been submitted to DWR by the PVWMA and the Santa Cruz Mid-County Groundwater Agency, and has been "approved as-modified".

The extent of the PVGB (Figure 2.1) for the purposes of this SNMP is the eastern boundary of the PVWMA statutory boundary located along the county line dividing Santa Clara and Santa Cruz Counties until it comes into contact with the San Andreas Fault, which extends through the eastern portion of the PVWMA service area and is a hydrogeologic groundwater flow barrier within the groundwater basin. Due to the lack of groundwater connection, the relatively small area (~7 sq miles) east of the San Andreas Fault is not included in this SNMP analysis nor is it considered a part of the PVGB. The northern border of the PVWMA service area is a jurisdictional boundary with little hydrologic basis, except where it coincides with the drainage divide between Aptos Creek and the Pajaro River (PVWMA 2014). The southern boundary of the PVWMA jurisdictional boundary reflects groundwater and surface water physical divides. In Elkhorn Slough, the PVWMA border follows the groundwater divide separated by the mostly impermeable clays. Further inland, the border follows the surface water divide. In the inland area, there are no geologic barriers to groundwater movement, which can vary due to hydrologic conditions or groundwater extraction (PVWMA 2014). Considering the various hydrologic and physical barriers to groundwater movement, this report will define the PVGB as the area within the PVWMA jurisdictional boundary to the west of the San Andreas Fault. While there are areas to the north and south of PVWMA's jurisdictional boundary that are hydrologically connected to the groundwater basin, the narrower definition of the PVGB coincides with management boundaries and where PVWMA continues to conduct extensive monitoring. The Pajaro Valley Hydrologic Model Boundaries (Chapter 3) does include areas outside of PVWMA's jurisdictional boundaries (including offshore areas). However, it is assumed that the PVGB boundary definitions used in this SNMP reasonably represent conditions within the Pajaro Valley and are at the most useful spatial scale to inform management decisions.

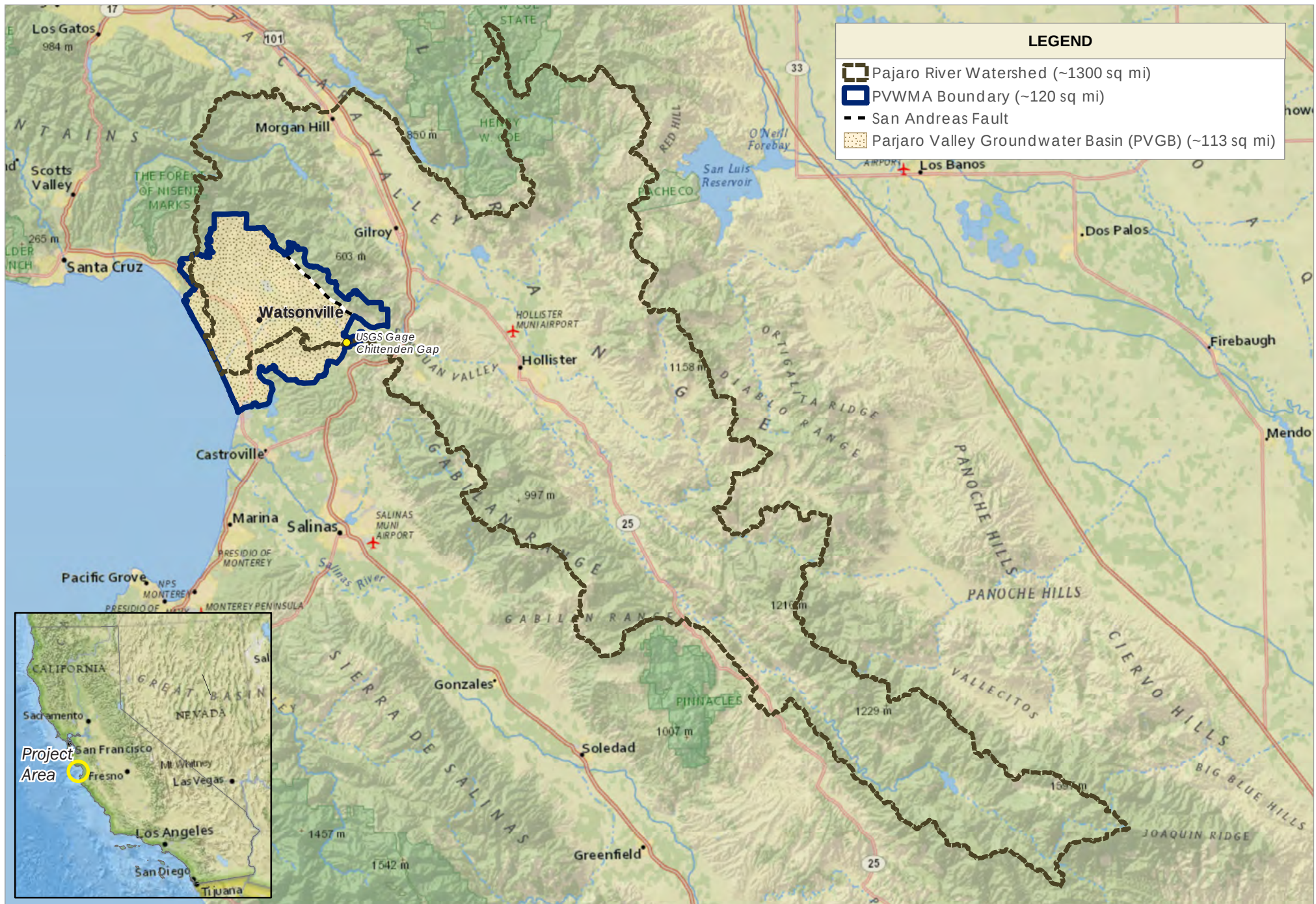


FIGURE 2.1: SNMP project area, location and geography.

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## 2.2 PVGB Physical Setting

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### 2.2.1 GEOLOGIC STRUCTURE

In order to appreciate the complex nature of groundwater availability and management within the PVGB, a basic understanding of the geologic structure of the basin is necessary. The PVGB is an alluvial basin composed of multiple interconnected hydrogeologic units, which are bounded by the San Andreas Fault complex to the east and Monterey Bay to the west, that together define the relationship between groundwater recharge, extraction, levels and quality (PVWMA 2014). Pliocene to Holocene deposits underlie the basin with a maximum thickness of 4,000 ft. Ordered from oldest to youngest, these include the Purisima Formation, Aromas Red Sands, terrace deposits, and dune sand (Muir, 1972).

The Purisima Formation consists of layers of sandy silts and silts that were deposited in a marine environment. It is penetrated by only a few deeper wells in the coastal portion of the basin, and by a greater amount of wells located in the foothills, where the aquifer is shallower due to the San Andreas Fault. The Purisima Formation has a lower transmissivity than the overlying Aromas Red Sands. Consisting primarily of well-sorted brown and red sands deposited by a combination of fluvial and aeolian processes, the Aromas Red Sands aquifer is the primary water bearing unit in the basin (PVWMA, 2014). The alluvial aquifer and the terrace deposits tend to be penetrated by older, shallower wells. Clay layers are scattered throughout the aquifer, which limit vertical water movement in some areas (PVWMA 2014). A sophisticated hydrologic model of PVGB groundwater is described in detail in Chapter 3.

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### 2.2.2 CLIMATE AND WEATHER

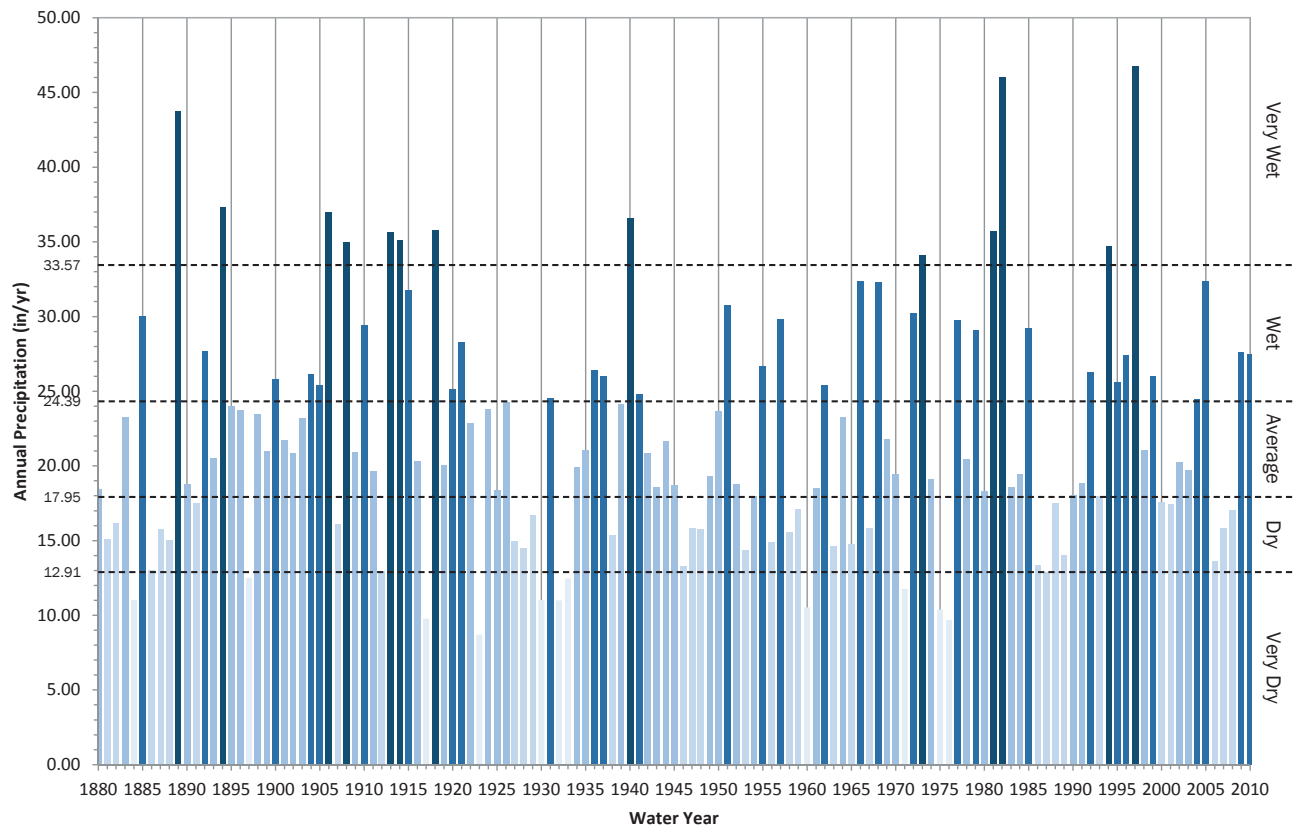
The Pajaro Valley is typified by a Mediterranean climate with its characteristic warm and mostly dry summers and cool, wet winters. The temperature moderating Monterey Bay results in fog and low overcast clouds, particularly during the summer. The average temperature is 57.4 degrees Fahrenheit, with the average high and low temperatures of 67.8 degrees Fahrenheit and 46.9 degrees Fahrenheit, respectively ([U.S. Climate Data](#)).

The distribution of rainfall within the Pajaro Valley varies geographically, with higher elevation areas generally receiving greater amounts of precipitation. The majority of the rainfall (72%) occurs during the winter months between December and March (PVWMA 2014). A historical precipitation frequency analysis was conducted to define water year types based on water year precipitation totals within the PVWMA boundary (Figure 2.2). The frequency analysis was carried out with data collected at the [Watsonville Water Works](#) station between 1880 and 2011. Over this period, the average annual rainfall was 21.9 inches. This classification of water year type provides climatic context to expected year to year variability of many key processes potentially influencing annual constituent loading to the groundwater basin such as groundwater recharge, groundwater extractions, irrigation volumes, groundwater quality, and seawater intrusion.

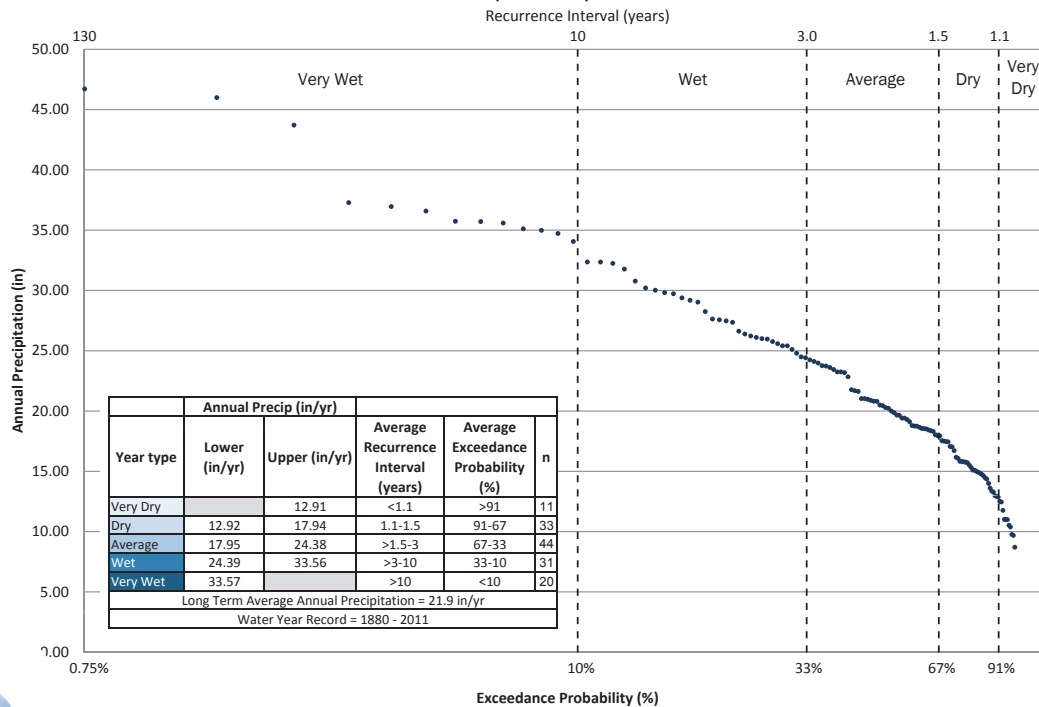
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# WATER YEAR CLASSIFICATION

Watsonville Water Works Station



## Frequency Analysis of Annual Precipitation Watsonville Water Works Station (1880-2011)



2NDNATURE LLC



TEL : 831.426.9119 FAX: 831.426.7092

www.2ndnaturellc.com

PRECIP FREQUENCY ANALYSIS - WATSONVILLE WATER WORKS

FIGURE 2.2

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### 2.2.3 SURFACE WATER

With a drainage area of about 1,300 square miles, the Pajaro River is the largest stream passing through the PVGB. The Pajaro River is [gaged at Chittenden Gap](#), near the eastern boundary of the PVWMA. Annual stream flow recorded by the United States Geological Survey (USGS) in the Pajaro River at this location averaged 164 cubic feet per second (CFS) between 1940 and 2011. The flow from the upper areas in the Pajaro River watershed contribute substantial volumes of water to the PVGB through seepage to groundwater (Hatch, 2009). Approximately half of the PVWMA jurisdictional boundary drains through the Corralitos Creek and College Lake Watersheds to the Pajaro River (PVWMA 2014). The northwestern portion of the PVWMA area is drained through a network of sloughs. The slough systems experience a great deal of seasonal variation, with upper reaches dry though much of the year. The shallow open channels of the lower reaches are generally inundated year-round draining to the Pajaro River Lagoon and out to Monterey Bay when the channel is open (PVWMA 2014). The one significant stream reach within the PVWMA service area that does not drain to the Pajaro River Lagoon is Carneros Creek. Carneros Creek enters the PVWMA boundary from the south and eventually drains into Elkhorn Slough.

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### 2.2.4 GROUNDWATER

The Pajaro Valley is highly dependent on groundwater to meet the needs of water users. Groundwater accounts for 98% of the total water supply, with the other 2% coming from a combination of surface water and recycled water use. Inflows to the groundwater system include streamflow infiltration, direct infiltration from precipitation, irrigation return flows, underflow from adjacent basins, and seawater intrusion. Groundwater production dominates outflows from the groundwater system, but outflow of the basin also occurs when groundwater discharges to the bay or is consumed by vegetation with deep roots. Chapter 3: Groundwater Budget provides more detail into the volumes of inflows and outflows.

The PVGB behaves similar to a closed basin under recent and current groundwater conditions. Most groundwater flowing into the PVGB does not have an opportunity to naturally flow out of the basin unless it is extracted by well pumping. This is due to depressed groundwater levels within the center of the valley, an impact of long-term groundwater overdraft. The result is that groundwater flow from most directions is toward the center of the valley, where water levels are lowest (Figure 2.3). This includes most subsurface flow from Monterey Bay, which occurs in the basin as seawater intrusion.

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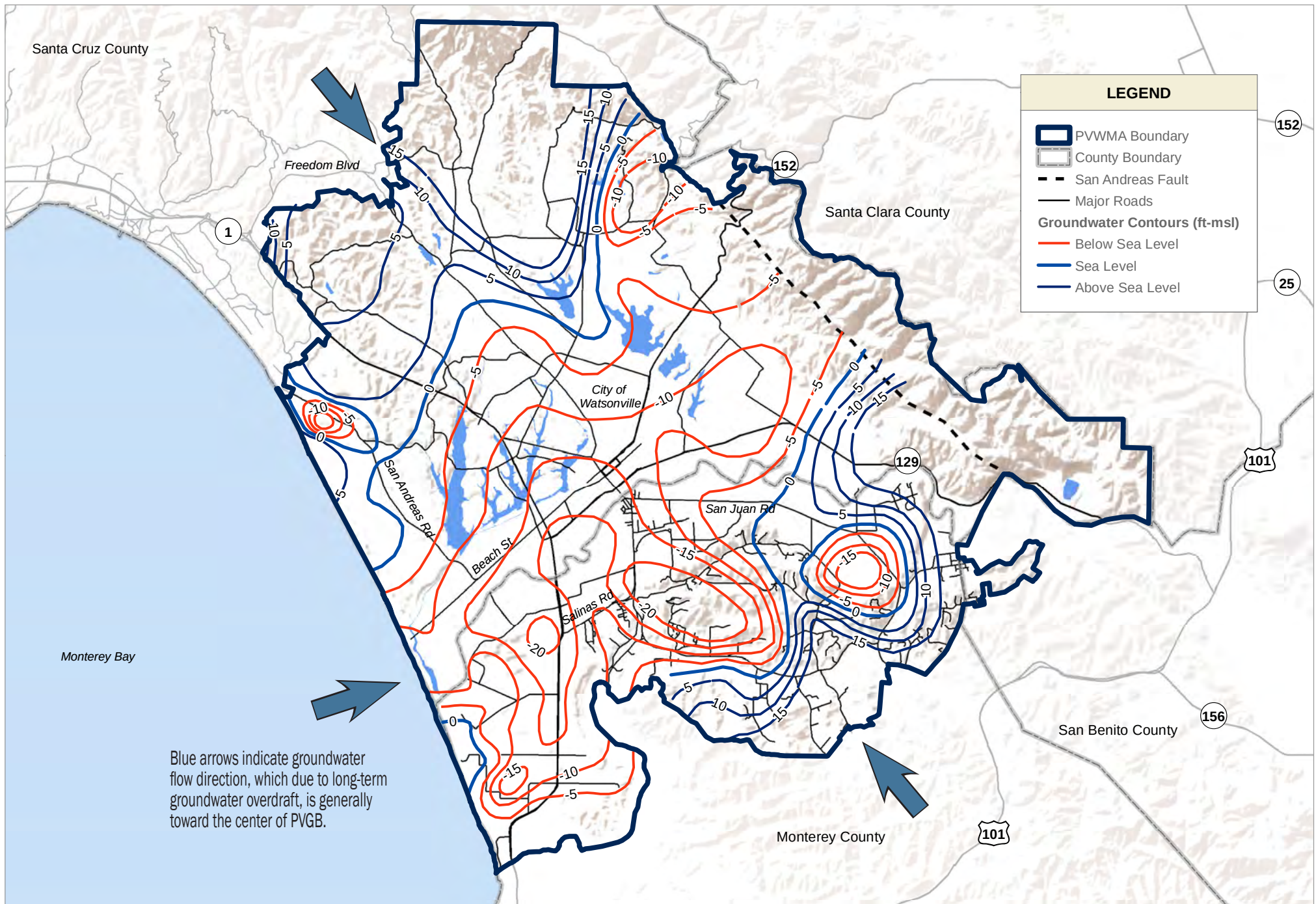


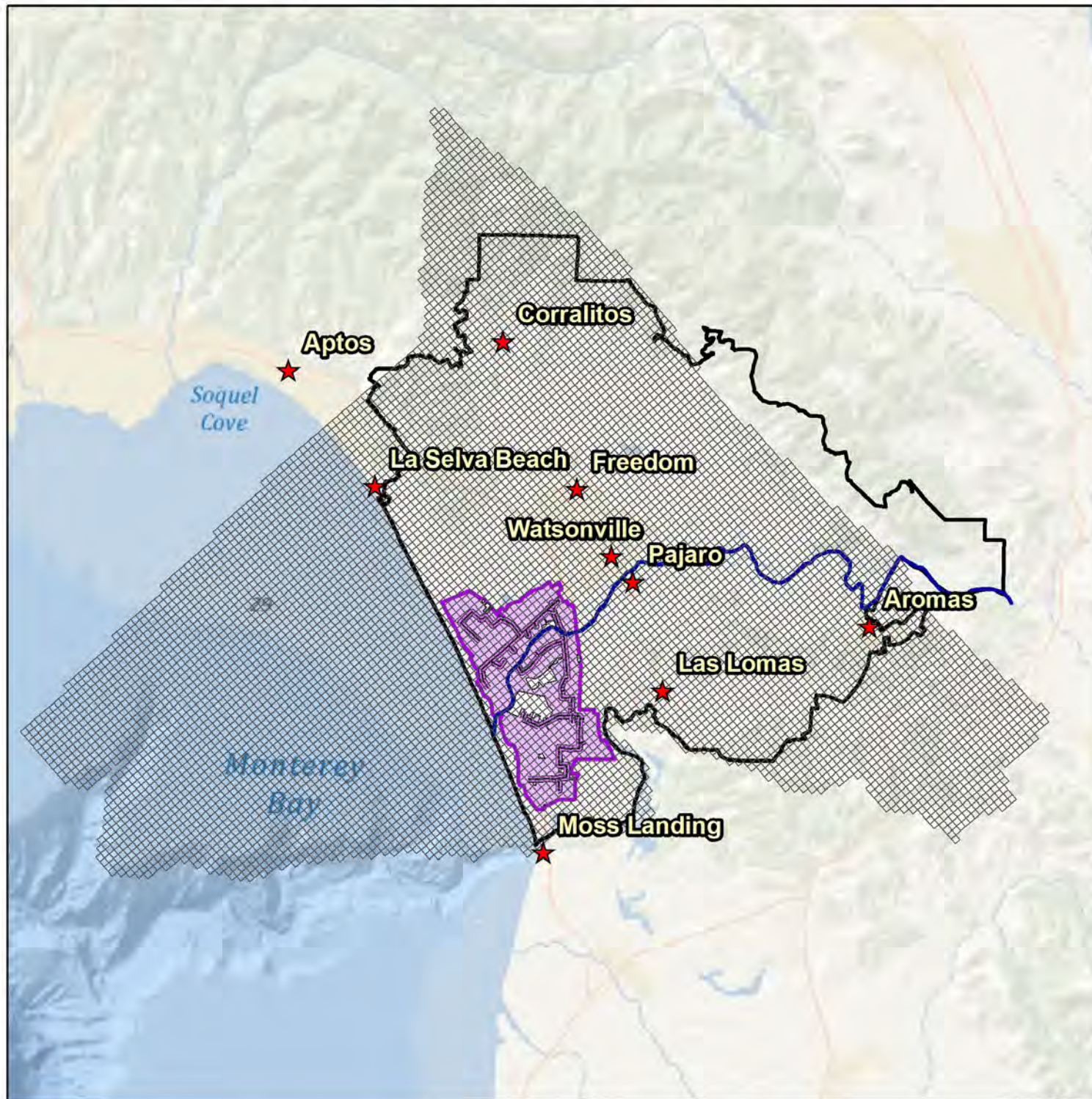
FIGURE 2.3: PVGB groundwater contours (2008)

### 3 GROUNDWATER BUDGET

PVWMA began working with the USGS in 2005 to develop the [Pajaro Valley Hydrologic Model \(PVHM\)](#), a robust hydrologic model of groundwater flows within Pajaro Valley. The PVHM model boundaries extend beyond the jurisdictional boundary of the PVWMA (Figure 3.1). To the west, the model extends into Monterey Bay for several miles. The northern and southern boundaries also extend beyond the jurisdictional boundaries of the PVWMA. The PVHM incorporates past and current climate and weather data, land use, water deliveries and more, and it simulates groundwater pumping (available as a result of PVWMA's programs established in the mid-1990s), which is compared to actual production data to check the accuracy of the model. The model has been and continues to be used to estimate the water budget for PVGB, and to estimate the order of magnitude offset in the PVGB water budget. During a stakeholder driven process to update the Basin Management Plan, the PVHM was utilized to evaluate the effectiveness of various proposed water management scenarios in meeting the goals of stopping groundwater overdraft and halting seawater intrusion. The PVHM continues to be improved upon to more accurately reflect current conditions and to better predict potential climate change impacts on the PVGB. RT Hanson of the USGS provided the most recent update to the Groundwater Budget Summary (Table 3.1) in July of 2015.

The PVHM was designed to reproduce the natural and human components of the hydrologic system and related climatic factors, so that the components of the Basin Management Plan are adequately and accurately represented. Of particular importance was to assess amounts of overdraft and seawater intrusion into the Alluvial aquifer and Aromas Red Sands aquifer where most groundwater extraction occurs (PVWMA 2014). In developing the PVHM, the conceptual model and the hydrogeologic framework of the Pajaro Valley were refined from what had been used in previous modeling efforts. The conceptual model identified inflows and outflows that include the movement and use of water from natural and human components. The groundwater flow system, influenced by the permeability of layered sediments, may be characterized by vertical hydraulic gradients. These vertical gradients are the result of the application of irrigation water at the land surface, direct infiltration by rainfall, and groundwater extraction. Agricultural groundwater extraction is the major component to simulated outflow; therefore, a coupled farm-process model is used to estimate historical extraction for water-balance subregions as well as the delivery of surface water to and from the Harkins Slough Aquifer Storage and Recovery System (HS-ASR) and related coastal distribution system (CDS). The integrated hydrologic model includes new water-balance subregions, delineation of natural, municipal, and agricultural land use, streamflow networks, and groundwater flow systems. Redefining the hydrogeologic framework (including the internal architecture of the deposits) and incorporation of these units into the simulation of the regional groundwater flow system indicate the importance of the basal confining units. Altering the parameters of the basal confining units in the alluvial deposits and upper and lower Aromas sands result in changes in groundwater flow, locations of recharge, and effects of development.

Table 3.1 summarizes the water budget (inflows and outflows) within the active model grid (Figure 3.1) comparing average annual groundwater flux estimates for a recent 5-year period (2005-2009) and representative recent wet (2006) and dry (2008) water years. The PVHM suggests the primary inputs to the PVGB are direct infiltration and recharge occurring in surface water streams, with a relatively lower contribution via stream recharge during dry years. Groundwater pumping is the greatest outflow from the PVGB, with minimal volume differences between wet and dry years. The groundwater budget suggests the difference between inflows and outflows during a simulated dry year



# PVWMA Boundary & PVHM Boundary

## Explanation

- ★ Cities & Towns
- Pajaro River
- CDS Alignment
- Delivered\_Water\_Zone
- PVHM Active Model Cells
- PVWMA Boundary

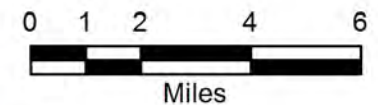


Figure 3.1



may exceed 40,000 AFY. The water budget simulated over the 5-year period (2005 – 2009) resulted in an average deficit of 9,800 AFY. The PVHM results suggest net recharge is possible during wet years, as exemplified in 2006 when storage accretion was 17,500 acre-feet.

**Table 3.1:** PVHM groundwater budget summary updated July 2015. Average flows reported in acre-feet per year and rounded to the nearest hundred. (R.T. Hanson, USGS, written communication, July, 2015).

| Time Period (Water Years)                 | 2005-2009     | 2006 (Wet)    | 2008 (Dry)     |
|-------------------------------------------|---------------|---------------|----------------|
| <b>Inflows</b>                            |               |               |                |
| Landward Underflow <sup>4</sup> (LU)      | 3,420         | 3,150         | 3,780          |
| Net Direct Infiltration <sup>2</sup> (DI) | 31,320        | 37,190        | 23,470         |
| Streamflow Infiltration <sup>2</sup> (SI) | 14,960        | 20,100        | 10,460         |
| Total Recharge (DI+SI):                   | 46,280        | 57,290        | 33,930         |
| Total Onshore Inflows:                    | 49,700        | 60,440        | 37,710         |
| <b>Outflows</b>                           |               |               |                |
| Storage Depletion <sup>2,3</sup>          | 2,260         | -8,710        | 17,250         |
| Storage Depletion <sup>3,4</sup> (SWI)    | 2,550         | 1,470         | 2,670          |
| Outflow to Bay <sup>2,4</sup> (OB)        | 580           | 110           | 0              |
| Rural Residential Pumpage <sup>2</sup>    | 1,470         | 1,430         | 1,490          |
| Water Supply Pumpage <sup>6</sup>         | 9,550         | 9,480         | 9,630          |
| Agricultural Pumpage                      | 43,090        | 39,150        | 47,650         |
| Total Pumpage <sup>5</sup>                | 54,110        | 50,060        | 58,770         |
| Total Discharge:                          | 59,500        | 42,930        | 78,690         |
| <b>Inflows – Outflows<sup>8</sup> =</b>   | <b>-9,800</b> | <b>17,510</b> | <b>-40,980</b> |

<sup>1</sup>Average flows in acre-feet per year. Water Year is October through September of the following year.

<sup>2</sup>Estimated from (farm Net Zone & WtrYr) from spreadsheet WBS\_PVHM\_03102011.xlsx

<sup>3</sup>Estimated for Onshore Portion of the Active Model Grid

<sup>4</sup>Estimated from (gswi Net Zone & WtrYr) from spreadsheet WBS\_PVHM\_03102011.xlsx

<sup>5</sup>Estimated from (FDS AFY by Farm and Water Year) from spreadsheet WBS\_PVHM\_03102011.xlsx

<sup>6</sup>Estimated from (FDS AFY by Farm and Water Year) from spreadsheet WBS\_PVHM\_03102011.xlsx

<sup>7</sup>Excludes water-balance subregions for Soquel Creek (21) and Central (23) Water Districts

<sup>8</sup>Negative number indicates storage depletion and positive number indicates storage accretion

In order to determine the total water deficit that the BMP Update would need to mitigate, USGS in collaboration with staff ran the PVHM through a 30-year simulation (1976 to 2006). Based on the results, PVWMA established a target of reducing groundwater production in the Pajaro Valley groundwater basin by 12,100 acre-feet per year (AFY). While these numbers show a different shortfall than the results for the more recent simulation results shown in Table 3-1, it is important to note that the time periods for the two simulations are different. Furthermore, the PVHM continues to be improved and updated to more accurately represent the PVGB water budget. While the BMP uses the 12,100 AFY target, the loading analysis in this report will rely on the more recent results shown in Table 3.1.

## 4 SALT AND NUTRIENT EXISTING CONDITIONS

The extensive surface water and groundwater quality data collected by PVWMA as a result of its comprehensive basin monitoring programs were evaluated to determine existing salt and nutrient conditions within the PVGB. Groundwater quality varies significantly throughout the PVGB (in x, y, and z directions), and statistical data interpolation techniques were utilized to characterize the existing conditions throughout the Basin. Prior to presenting the integrated data, the rationale for selecting each of the salt and nutrient constituents is provided.

### 4.1 Constituents of Concern and Relevant Sources

For the purpose of establishing PVGB baseline water quality conditions in this SNMP, several key indicator constituents were selected through a stakeholder driven process. A broader constituent evaluation was conducted initially, in order to select the salt and nutrient compounds would be most effective in meeting the SNMP development objectives. A range of salt and nutrient compounds were considered for inclusion based on their respective fate and transport in the environment, availability of local groundwater datasets, and biogeochemical behavior relative to other salt or nutrient compounds. After consideration and a discussion with the stakeholders in attendance at SNMP Stakeholder Meeting #1, the final priority constituents selected for the SNMP include Total Dissolved Solids (TDS), Chloride (Cl) and Nitrate (NO<sub>3</sub>).

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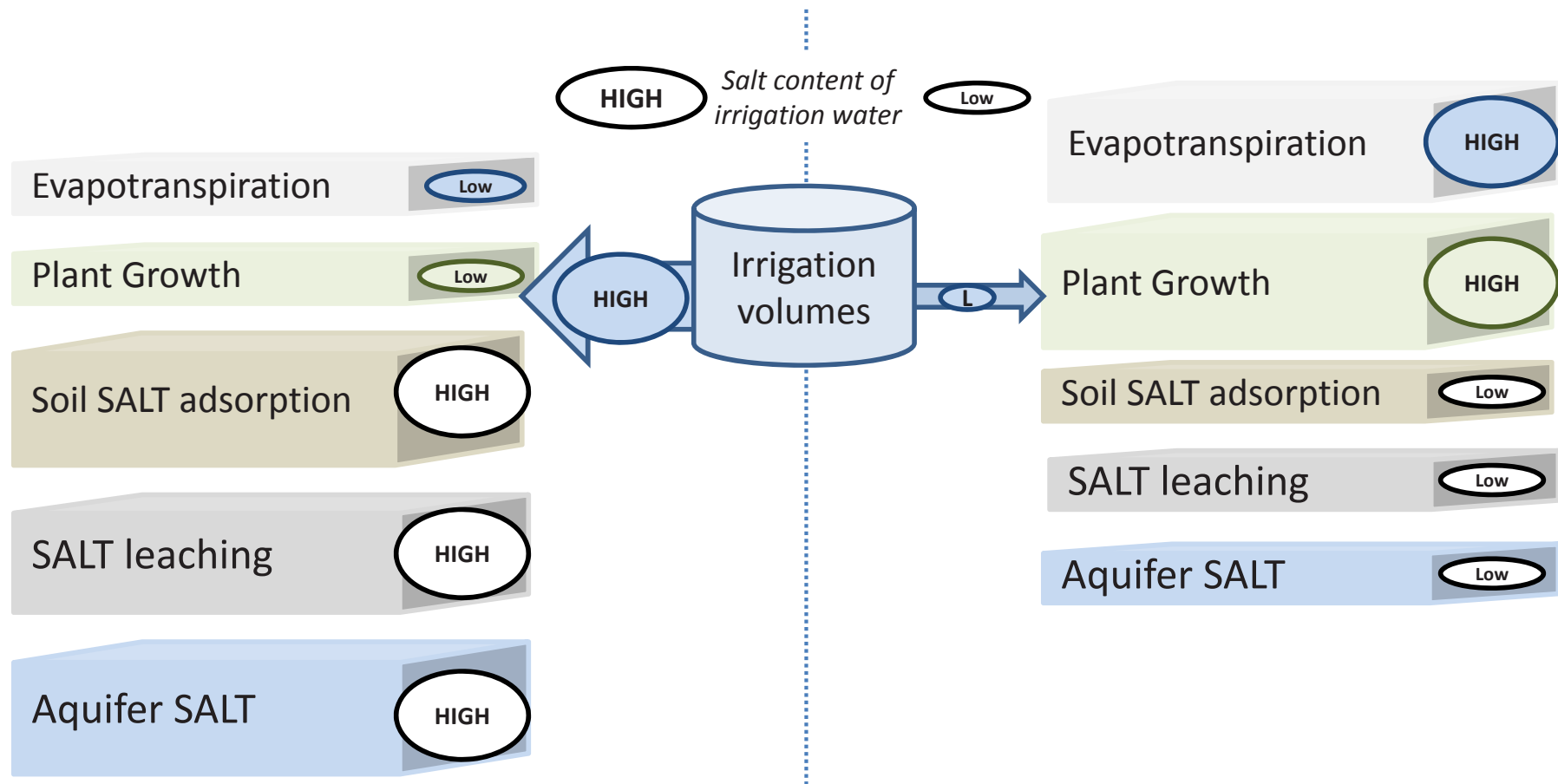
#### 4.1.1 TOTAL DISSOLVED SOLIDS (TDS)

The use of Total Dissolved Solids, or TDS, as a water quality parameter is a common and cost effective way to represent salinity. TDS is defined as the combined content of organic and inorganic constituents that remain in a water sample following filtration through a 2 µm sieve. TDS is composed of the following primary constituents, making it a simple and universal proxy for the bulk salt content of water: calcium, phosphates, nitrates, chloride, sodium, and potassium. PVMWA staff conducts extensive groundwater and surface water TDS sampling, providing a breadth of both spatial and temporal TDS concentration data. The primary pathways in which elevated salt concentrations can be transported to the PVGB include seawater intrusion (Chapters 4.12 and 5.1.1), surface water infiltration (Chapter 5.1.2), and streamflow infiltration (Chapter 5.1.3). This SNMP will evaluate salt loading from seawater intrusion (Chapter 5.2.1), irrigation practices (Chapter 5.2.2), and stream recharge (Chapter 5.3.3).

Irrigation practices may result in elevated TDS concentrations in soil. High concentrations of TDS in the soil may result in negative impacts on agriculture, which is vital to the economy of the Pajaro Valley. For salt sensitive crops, such as strawberries, ideal TDS concentrations in irrigation water are less than 450 mg/L. Irrigation practices may result in salt accumulation in the topsoil, which periodically needs to be flushed below the root zone by a combination of rainfall and irrigation in order to maintain or improve soil quality. Components of the salt cycle and associated effects on aquifer salt impacts from crop irrigation practices are illustrated in Figure 4.1. The salt content (measured as TDS concentration) of irrigation waters has a significant impact on the relative salt leaching to the underlying aquifer due to plant sensitivity to elevated TDS content, potentially requiring greater volumes of water application in the absence of rainfall in order to achieve optimal plant growth.

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## SALT CYCLING ON IRRIGATED LAND



*A simple comparison of the salt cycling and associated effects of the total salt content of the irrigation water applied to crops. The potential salt sensitivity of plants can result in reduced plant growth and the fraction of water lost to evapotranspiration. Higher salt contents of irrigations waters also result in a greater rate of salt buildup in the soil, requiring a greater volume of irrigation water required to leach salts from the soil. The increased irrigation volumes transport the excess soil salt vertically into the groundwater aquifer.*



The current [Water Quality Control Plan for the Central Coast Basin](#) (Basin Plan, 2016) does not list any specific TDS groundwater objectives for the PVWMA area. Objectives for other groundwater basins in the Pajaro River watershed include 300 mg/L for the Llagas basin, 1000 mg/L for the Tres Pinos basin, and 1200 mg/L for the Hollister basin.

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#### 4.1.2 CHLORIDE (Cl)

Chloride, or Cl, was chosen as the primary constituent to track seawater intrusion. Chloride is an anion frequently occurring in nature as a salt, such as sodium chloride (NaCl), which happens to be the most common salt in seawater. A significant source of salts in the PVGB is due to seawater intrusion; a result of long-term groundwater overdraft. Seawater has a TDS concentration of about 35,000 mg/L, of which dissolved chloride comprises approximately 19,000 mg/L. Chloride dissolves in water, making it a useful constituent to track the spread of seawater intrusion into the groundwater basin. Chloride concentration contours have been used by PVWMA and others to track the movement of seawater intrusion into the PVGB since the 1950's. Areas that have chloride concentrations exceeding 100 mg/L are considered within the front of seawater intrusion. Given that TDS is a bulk measure of all salts, chloride has been included as a priority constituent of concern to provide additional data to distinguish between land use sources of salt (TDS) and elevated groundwater salt concentrations as a result of seawater intrusion (Cl). The current Water Quality Control Plan for the Central Coast Basin (CCRWQCB, 2016) does not list any specific chloride groundwater objectives for the PVWMA area. Objectives listed in Table 3-8 of the Basin plan for other groundwater basins in the Pajaro River watershed include 20 mg/L for the Llagas basin, 150 mg/L for the Tres Pinos basin, and 150 mg/L for the Hollister basin.

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#### 4.1.3 NITRATE (NO<sub>3</sub>)

Nitrogen and phosphorous are the two most widespread plant nutrients in the environment, and both are essential for primary production via photosynthesis. However, the fate and transport of these two nutrients in the environment are very different. Phosphate in water can exist in four different forms that are controlled by the pH of water. Three of these phosphate salts that are common in natural waters adhere to clay particles, making phosphate ions relatively less mobile in subsurface environments than key forms of dissolved nitrogen.

In contrast, nitrogen can exist in five different oxidation states and nitrogen cycling is very complex. Nitrate is the most common dissolved form in oxygenated environments and typically is the primary nitrogen (N) constituent used to identify surface water and groundwater nitrogen concentrations. Natural nitrate levels in groundwater are generally very low, with concentrations typically less than 10 mg/L for nitrate as nitrate (nitrate-NO<sub>3</sub>) or 2 to 3 mg/L for nitrate as nitrogen (nitrate-N). Nitrate is commonly reported as either nitrate-NO<sub>3</sub> or nitrate-N; and the value for one can be converted to the other by correcting for the mass difference of the two compounds.

Dissolved inorganic nitrate is a conservative anion in groundwater, meaning that with adequate soil moisture it can move through the subsurface without being retained or absorbed to the soil by ionic interactions with soils. Conversely, phosphate is generally considered a non-conservative constituent in groundwater with a high affinity to absorb to soil. The rationale for selecting nitrate as the nutrient proxy for the PVWMA SNMP was based on the following:

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1. The ability of nitrate to move through the subsurface without strong interaction with minerals in the groundwater means that it is a potential worst case scenario of the nutrient conditions.
2. Local surface water and groundwater datasets for nitrate-NO<sub>3</sub> are extensive.
3. Excessive nitrate in water can result in human health concerns making nitrate concentration standards in local waters more stringent than phosphate.
4. It is assumed that all anthropogenic sources of phosphate in the Pajaro Valley are also nitrate sources. Consequently, tracking phosphate would not provide additional information of value not already shown by nitrate.
5. The selection was vetted and accepted by the stakeholder committee.

A number of analytical methods are available to quantify the amount of nitrate in the biosphere. This SNMP will utilize nitrate-NO<sub>3</sub> to assess existing conditions within the PVGB. The loading analysis in Chapter 5.3 will also utilize nitrogen-N to maintain consistency with other loading analyses. Figure 4.2 is a simplified schematic of the nitrogen cycle relevant to the PVWMA SNMP and groundwater nitrate-NO<sub>3</sub> concentrations. Controllable anthropogenic sources are displayed in red boxes and the critical nitrogen biogeochemical processes are provided between each reservoir. The form, levels, and distribution of nitrogen within the PVGB varies significantly both spatially and temporally, and representation of this complexity is not intended with Figure 4.2, nor is it necessary to achieve the primary objectives of the SNMP.

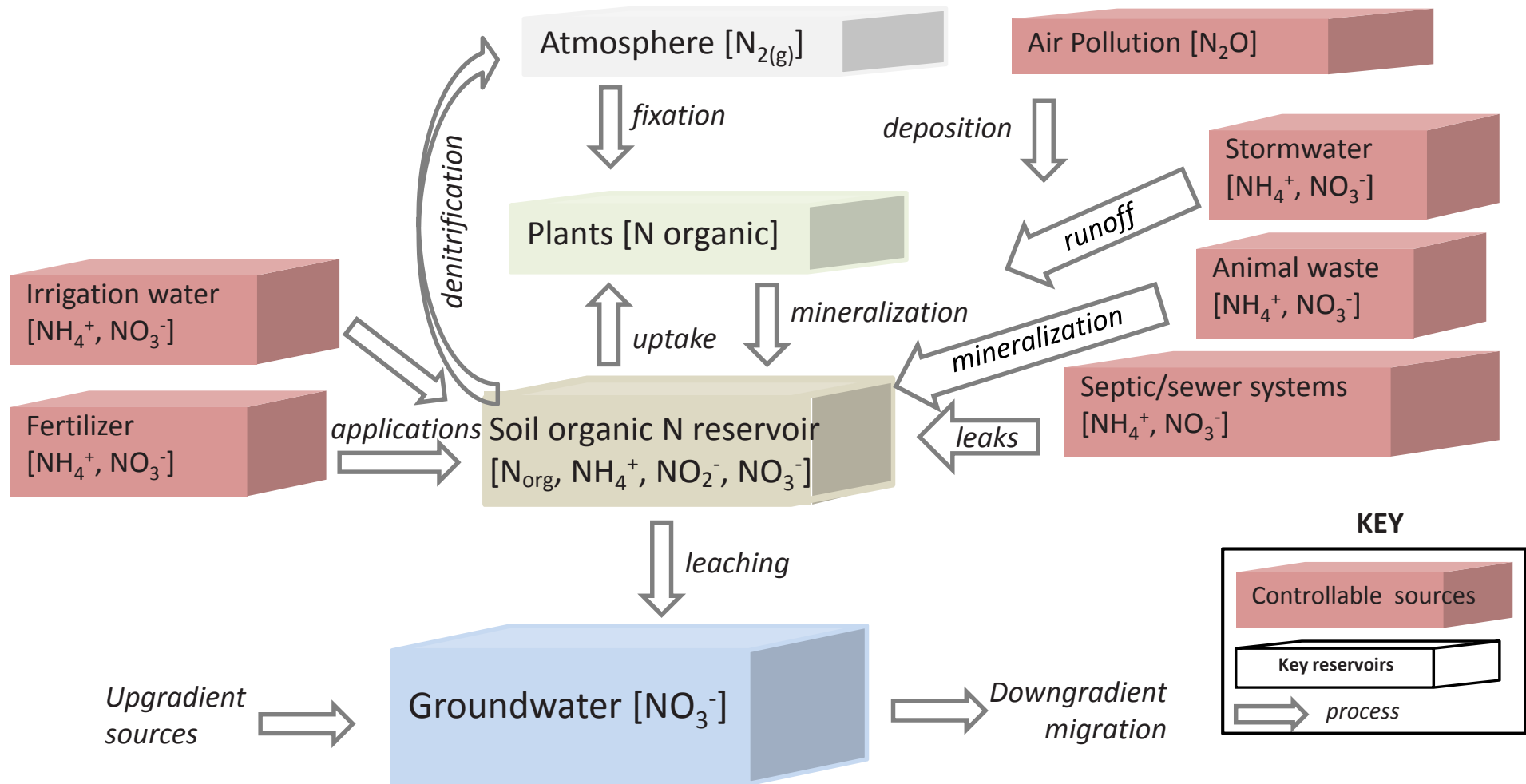
There are a number of state and federal water quality standards for nitrogen species potentially relevant to this SNMP. Table 4.1 presents the variety of standards and sources.

**Table 4.1:** Summary of relevant federal and state nitrogen standards.

| Regulation / document                                               | Standard                                   | Nitrogen constituent                                  | Value                   |
|---------------------------------------------------------------------|--------------------------------------------|-------------------------------------------------------|-------------------------|
| EPA National Primary Drinking Water Regulations (2009)              | Drinking water                             | Nitrate – N<br>Nitrate – NO <sub>3</sub> <sup>a</sup> | < 10 mg/L<br>< 45 mg/L  |
| Water Quality Control Plan for the Central Coast Basin (June, 2016) | Groundwater median water quality objective | Total nitrogen as N                                   | < 5 mg/L                |
|                                                                     | Beneficial Use Standards                   |                                                       |                         |
|                                                                     | AGR (irrigation)                           | Nitrate-N<br>Nitrate-NO <sub>3</sub> <sup>a</sup>     | < 30 mg/L<br>< 132 mg/L |
|                                                                     | AGR (livestock)                            | Nitrate – NO <sub>3</sub>                             | < 90 mg/L               |
|                                                                     | MUN                                        | Nitrate – NO <sub>3</sub>                             | < 45 mg/L               |

<sup>a</sup>Converted nitrate-N standard to nitrate-NO<sub>3</sub> using molar mass.

## Relevant components of the NITROGEN CYCLE



A simple schematic of the nitrogen cycle relevant to the PVWMA Salt and Nutrient Management Plan (SNMP) identifying the key considerations associated with observed nitrate concentrations in groundwater. Controllable anthropogenic sources are indicated as red boxes. Key reservoirs of nitrogen storage and transformations are noted with the predominant form of nitrogen indicated. The most critical form of nitrogen in groundwater is nitrate ( $NO_3^-$ ) due to its high solubility and transport in the subsurface.

## 4.2 Existing Conditions

This chapter leverages existing local data to document the existing surface and groundwater conditions with respect to the PVWMA SNMP constituents of concern.

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### 4.2.1 GROUNDWATER

Groundwater quality datasets from the PVWMA and the City of Watsonville were compiled to generate spatial representations of existing groundwater conditions for the three constituents of concern (TDS, Cl and NO<sub>3</sub>). PVWMA possesses an extensive water quality dataset from decades of sampling and monitoring wells within the PVGB. The temporal sampling of a specific well can range from a single sampling event to numerous samples resulting from long-term sampling programs. The City of Watsonville maintains 14 groundwater production wells within the City limits and surrounding area and samples these wells annually. The benefits and drawbacks of different data integration techniques were extensively evaluated prior to the selection of the recommended approach. The intent was to create representative maps that reasonably reflect existing groundwater conditions for the constituents of concern given the inherent seasonal and inter-annual variability of groundwater quality while maximizing the breadth of the available data. Data from over 300 sites (Figure 4.3) sampled between 2002 and 2011 were compiled to ensure a range of water year types were represented. The period 2002 - 2011 consisted of four dry, two average, and four wet water years (Figure 2.2).

Many of the wells sampled are privately owned and require methods of display that protect the anonymity of these locations and the confidentiality of the data. To accomplish this, the inverse distance weighted (IDW) toolset in geographic information systems (GIS) software was utilized to generate an interpolated surface based on the nearest five well locations. For each constituent, the decadal average and maximum concentration from each sampling location were integrated to summarize the existing groundwater conditions. It is assumed the average and maximum provide a representative range of existing conditions over the last decade. Documentation of the average decadal conditions is consistent with water quality standards as set by the CCRWQCB, which are typically based on average or median values from large datasets. The use of IDW as an interpolator is also consistent with other SNMPs developed for the Pajaro River Watershed.

A similar analysis on historical datasets prior to 2002 was not conducted for two primary reasons. The focus of the SNMP is to identify current conditions, existing sources, and develop strategies to protect and potentially improve future groundwater quality. Consequently, the recent groundwater data better represents current groundwater conditions. Furthermore, the recently completed Basin Management Plan (2014) provides an adequate summary of historic groundwater quality in Chapter 2, the State of the Basin, and may be referenced as necessary.

The spatial and temporal limitations of the dataset utilized to create Figure 4.4-4.9 are discussed below:

- Several wells were only sampled once and it is recognized that the values assigned to these sites may be influenced by the conditions at the time of sampling. However, these single concentrations were included in the analysis in order to increase the spatial resolution and temporal resolution of the summaries. The IDW statistical interpolation creates concentration contours using the five nearest monitoring wells, limiting the influence of individual samples on the final results.
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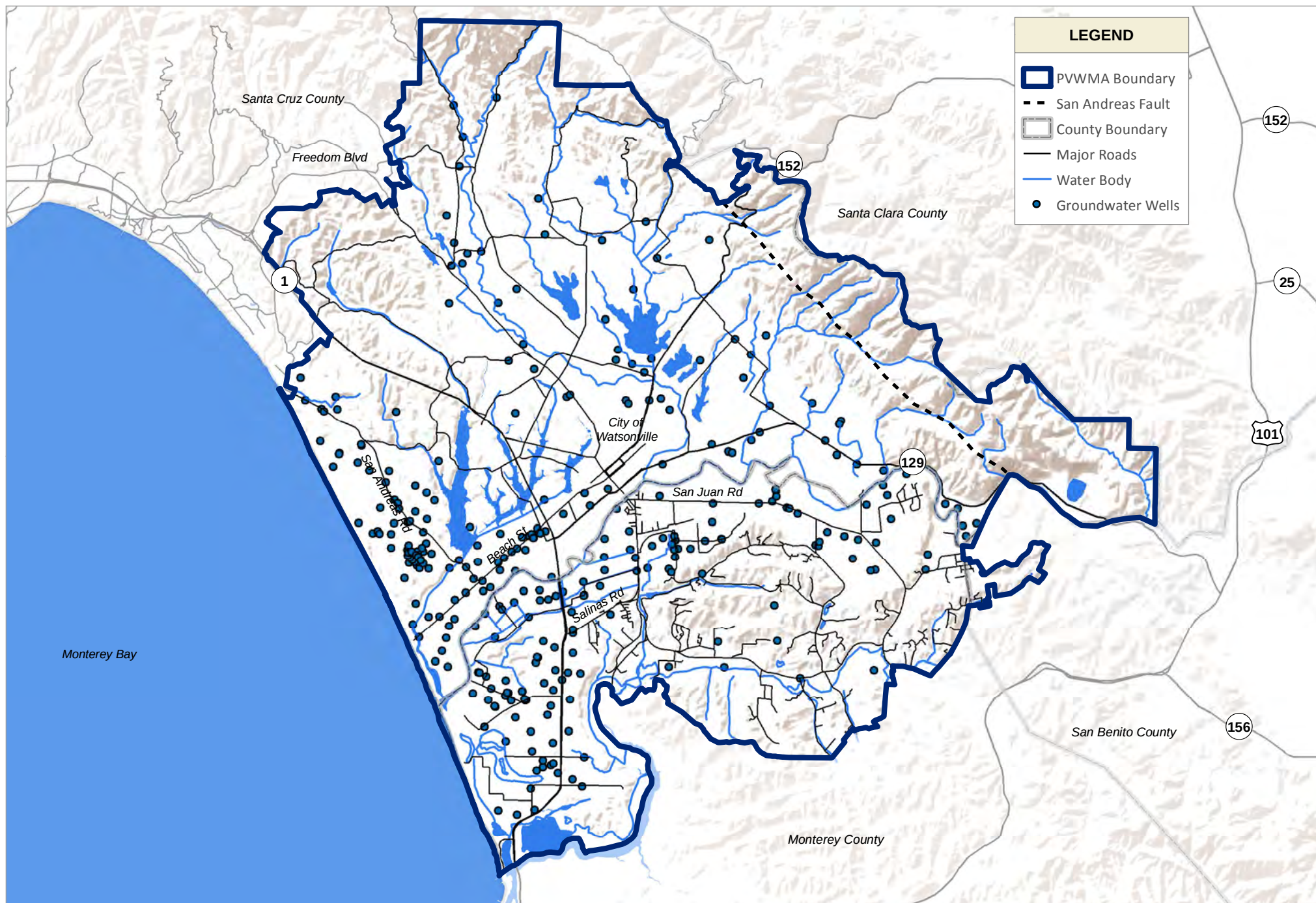


FIGURE 4.3: Location of 310 groundwater wells sampled for nitrate, chloride or TDS by PVWMA or the City of Watsonville between 2002-2011. Data used to document existing groundwater quality conditions.

- The hydrogeology of the PVGB is complex and the population of wells sampled is screened across a range of depths and different hydrogeologic units within the aquifer. The existing condition maps produced for this SNMP is a composite that combines spatial and geologic variations onto a single map, which represents average groundwater quality conditions.
- The temporal variability of groundwater quality is significant and can be influenced by climate, variations in groundwater inputs or outputs, and/or changes in the source loading. The summary of PVGB existing conditions is intended to represent the reasonable range of groundwater conditions that will adequately inform the identification of priority locations to implement effective management strategies.

#### 4.2.1.1 TOTAL DISSOLVED SOLIDS

TDS groundwater concentration distribution maps were created using 307 monitoring and production well locations and includes 1,692 discrete water quality samples collected by PVWMA and City of Watsonville from 2002 – 2011. The individual sample TDS concentrations ranged from a minimum of 45 mg/L to a maximum value over 27,000 mg/L. Using the IDW statistical interpolation method as described above, the average value from each monitoring site was used to create Figure 4.4 and the maximum value was used to create Figure 4.5. Results were grouped into four discrete concentration categories and acreage summaries provided in Table 4.2. The rationale for each category break is based on suitability for agriculture. Water with concentrations exceeding the standard could potentially have the following noticeable effects: hardness, deposits, color, staining, or a salty taste (EPA 2016).

- TDS concentrations < 450 mg/L are considered ideal for irrigation in order to minimize potential toxicity issues with crops as well as reduce the rate of soil salt accumulation and potential vertical leaching to the groundwater.
- TDS concentrations ranging from 451 - 1,000 mg/L are considered not optimal for long-term irrigation without mitigation, but are still adequate for salt tolerant crop production.
- TDS concentrations ranging from 1,001 - 1,800 mg/L are considered excessive for irrigation, are undesirable, and are generally not used for crop production.
- TDS concentrations > 1,800 mg/L are considered excessive in groundwater.

**Table 4.2:** Percent of PVGB area within concentration range for data in Figures 4.4 and 4.5.

| TDS<br>Concentration Range        | Decadal <b>MEAN</b> TDS<br>Figure 4.4<br>(% of PVGB) | Decadal <b>MAX</b> TDS<br>Figure 4.5<br>(% of PVGB) |
|-----------------------------------|------------------------------------------------------|-----------------------------------------------------|
| 230-450 mg/L                      | 55%                                                  | 44%                                                 |
| 451 mg/L – 1000 mg/L              | 39%                                                  | 45%                                                 |
| 1001 mg/L – 1800 mg/L             | 5%                                                   | 10%                                                 |
| >1800 mg/L                        | 1%                                                   | 1%                                                  |
| Spatially Weighted Concentration* | 527 mg/L                                             | 638 mg/L                                            |

\*Spatially weighted average basin concentration described in Chapter 7.2

Two locations exist within the PVGB where TDS concentrations are very high. These include the area proximate to the western boundary adjacent to Monterey Bay, which is consistent with the inland extent of the seawater intrusion front, and the eastern boundary of the PVGB near Murphy Crossing. Salty water originating from the upper reaches of the Pajaro River combined with high stream infiltration rates above Murphy Crossing have resulted in elevated TDS concentrations in the groundwater.

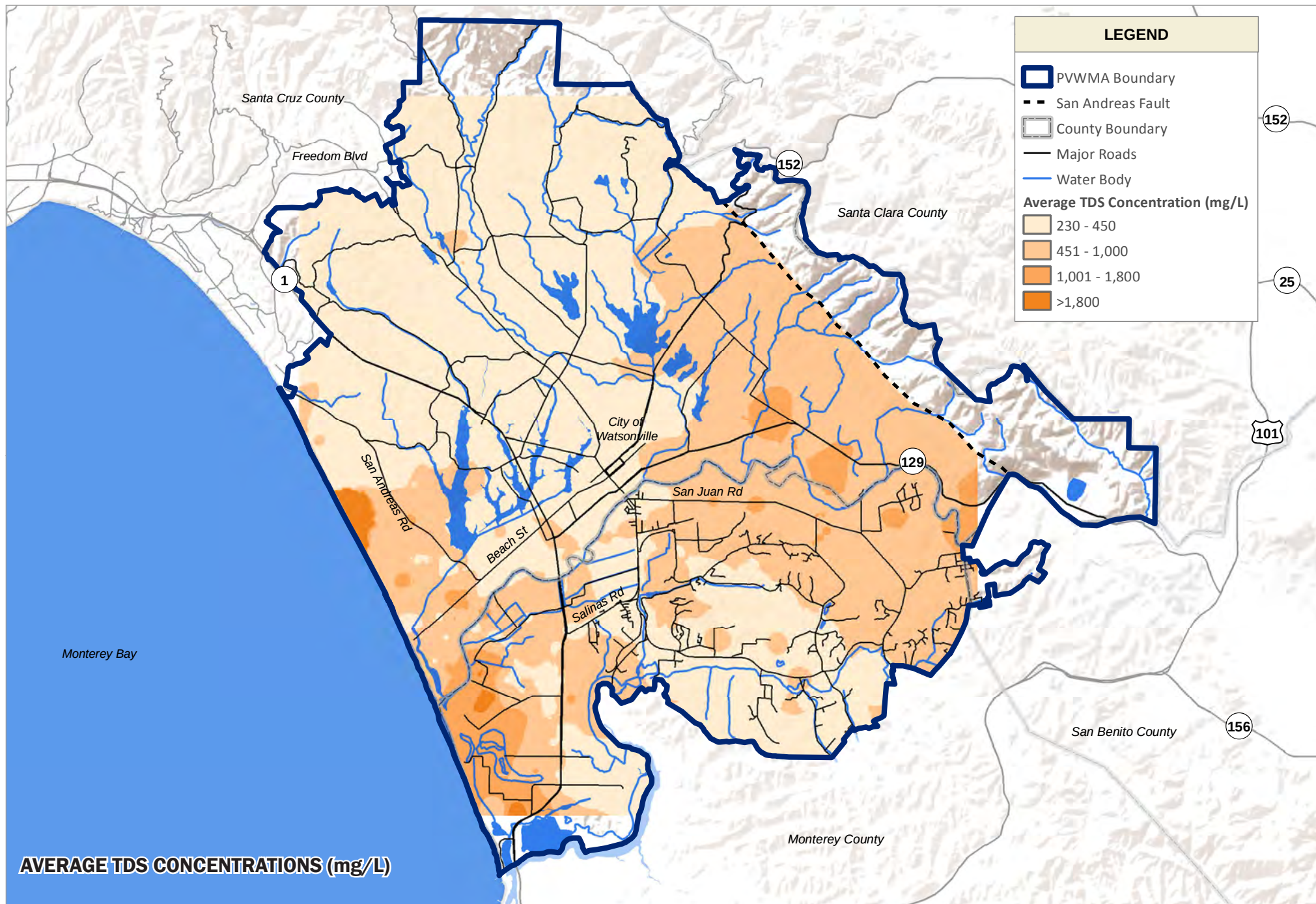


FIGURE 4.4: Interpolated average groundwater total dissolved solids (TDS) concentrations (mg/L) based on available PVWMA and City of Watsonville monitoring well data for 2002-2011.

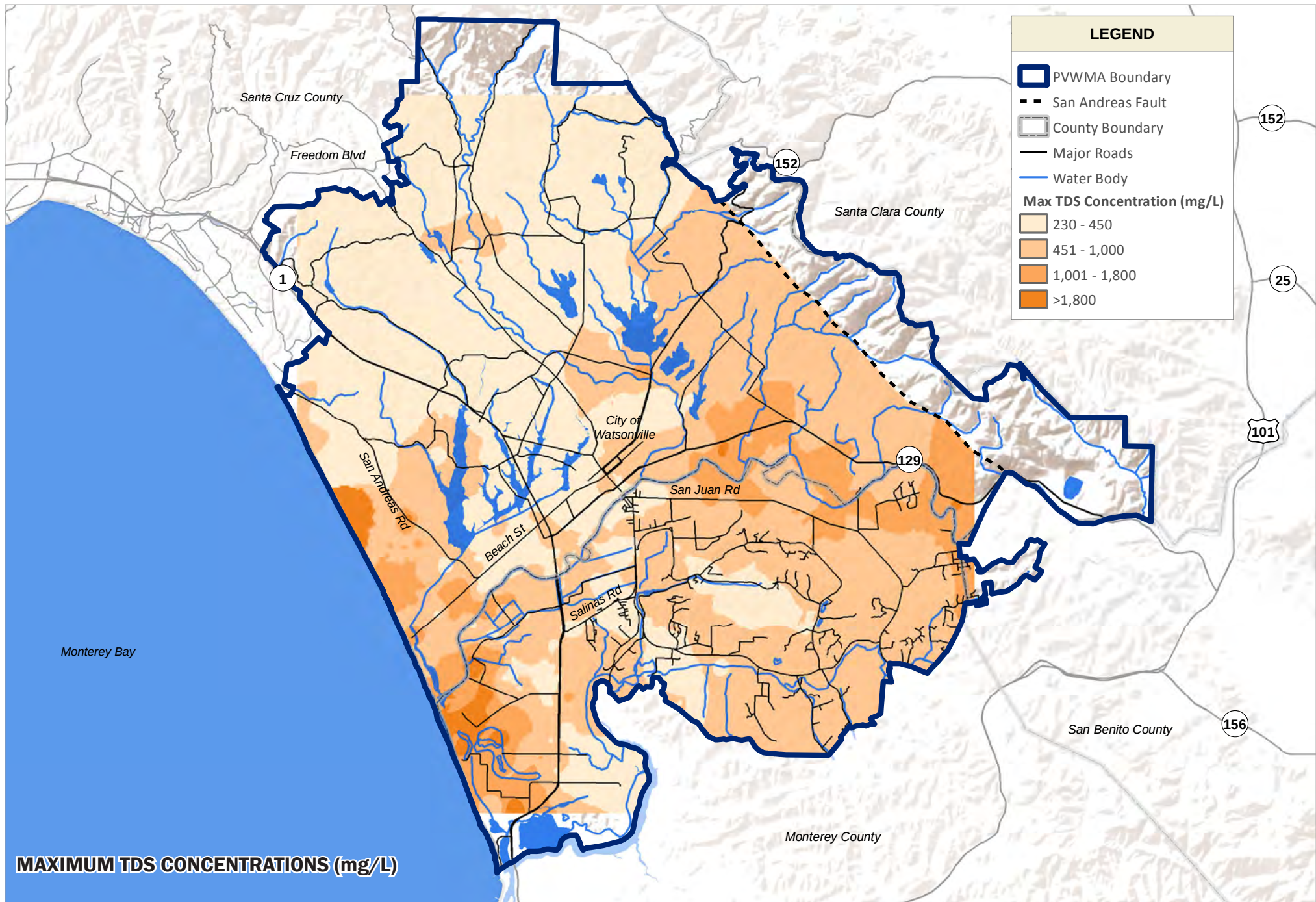


FIGURE 4.5: Interpolated maximum groundwater total dissolved solids (TDS) concentrations (mg/L) based on available PVWMA and City of Watsonville monitoring well data for 2002-2011.

### 4.2.1.2 CHLORIDE

Maps illustrating groundwater chloride concentrations were created using 308 monitoring and production wells and include 1,779 discrete water quality samples collected by PVWMA and City of Watsonville between 2002 and 2011. Individual chloride concentration samples ranged from a minimum of 3 mg/L to a maximum of 13,705 mg/L. Using the IDW method described above, the average value from each monitoring site was used to create Figure 4.6, and the maximum decadal values were used to create Figure 4.7, both of which are summarized in Table 4.3. Results were grouped into four discrete concentration categories:

- Groundwater chloride concentrations  $\geq 100$  mg/L trigger the inland SWI front in coastal areas.
- Chloride concentrations ranging from 101 – 250 mg/L are used as a common surface water standard.
- Chloride concentrations ranging from 251 – 500 mg/L used as a threshold between high and very high chloride.
- Chloride concentrations  $> 500$  mg/L used as indicator of locations with persistent, significant seawater intrusion.

**Table 4.3:** Percent of PVGB area within concentration range for data in Figures 4.6 and 4.7.

| Chloride<br>Concentration Range   | Decadal MEAN Cl<br>Figure 4.6<br>(% of PVGB) | Decadal MAX Cl<br>Figure 4.7<br>(% of PVGB) |
|-----------------------------------|----------------------------------------------|---------------------------------------------|
| 8-100 mg/L                        | 83%                                          | 80%                                         |
| 101 mg/L – 250 mg/L               | 12%                                          | 13%                                         |
| 251 mg/L – 500 mg/L               | 4%                                           | 5%                                          |
| $>500$ mg/L                       | 1%                                           | 2%                                          |
| Spatially Weighted Concentration* | 83 mg/L                                      | 103 mg/L                                    |

\*Spatially weighted average basin concentration described in Chapter 7.3

The seawater intrusion interface is a complex three-dimensional surface and the actual location of this dynamic boundary varies within each distinct aquifer by elevation and over time. PVWMA has generated a best approximation of the current (2011) inland extent of seawater intrusion as displayed on Figures 4.6 and 4.7. It is recognized however that areas of good groundwater quality exist within the intruded zone as noted by wells with CL  $< 100$  mg/L. Inland of the seawater intrusion boundary, most areas have chloride concentrations below 100 mg/L, with the exception of the groundwater west of Chittenden Gap near Murphy's Crossing.

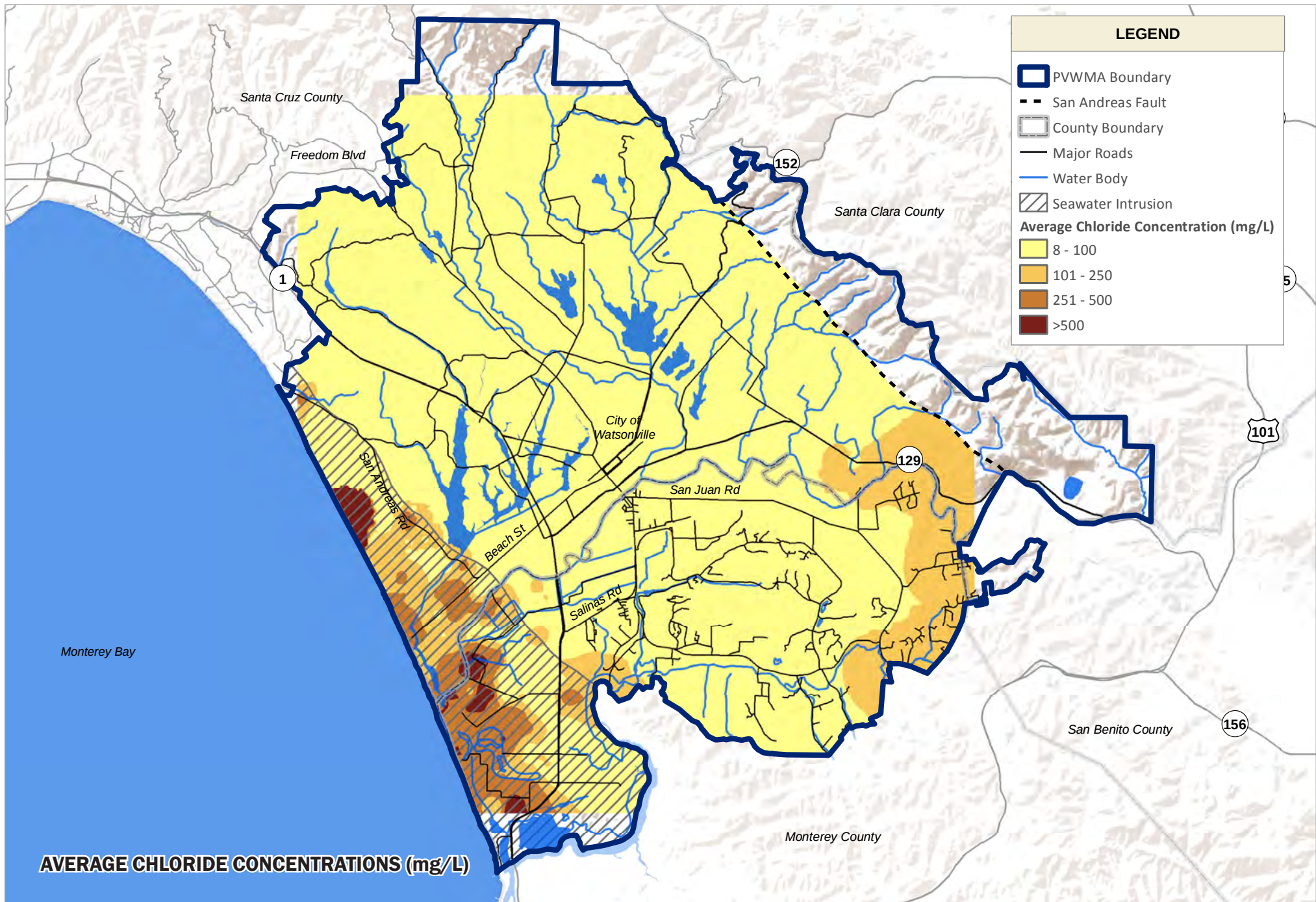


FIGURE 4.6: Interpolated average groundwater chloride concentrations (mg/L) based on available PVWMA and City of Watsonville monitoring well data for 2002-2011. Existing seawater intrusion front mapped by PVWMA based on chloride groundwater quality data (PVWMA, 2011).

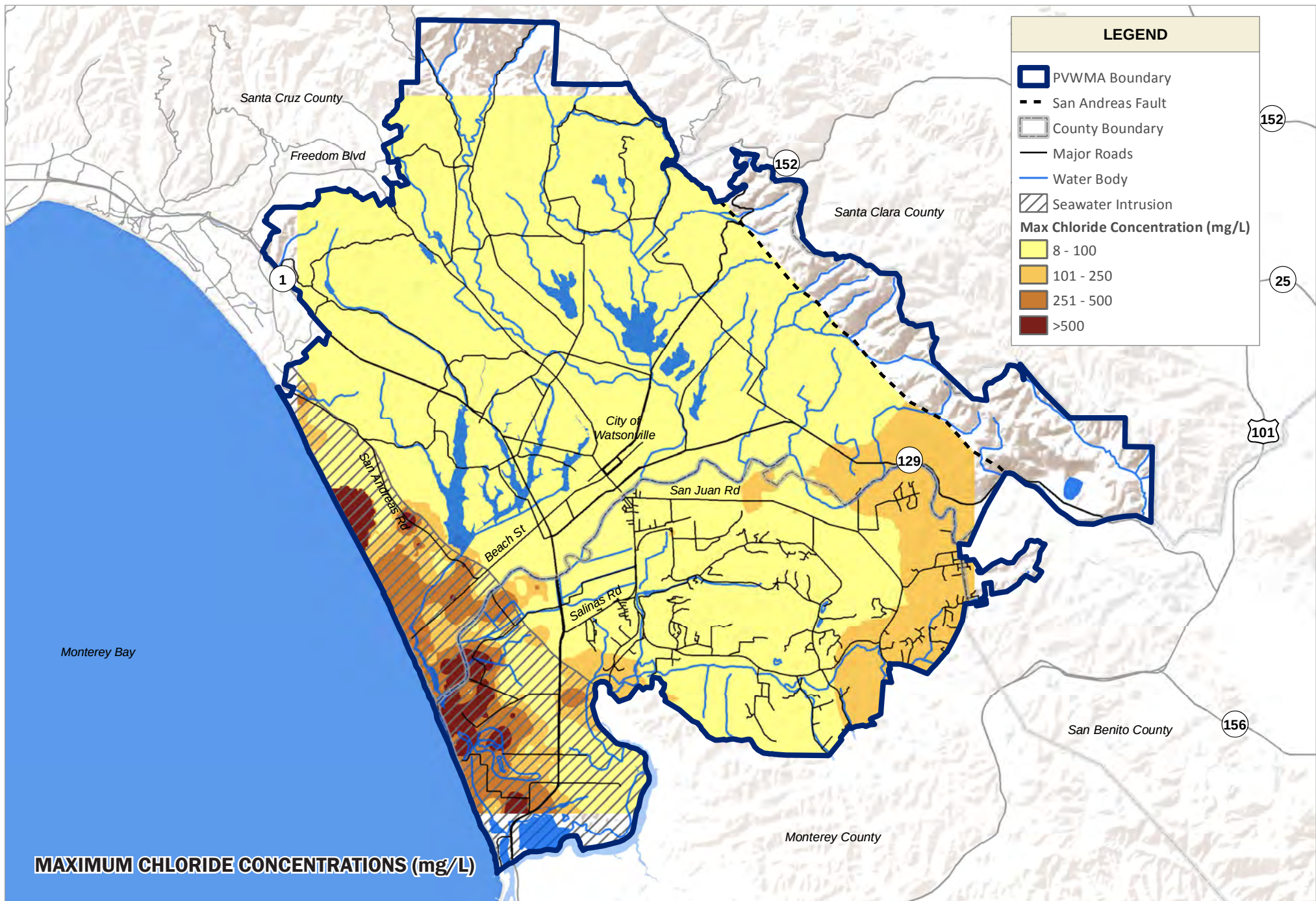


FIGURE 4.7: Interpolated maximum groundwater chloride concentrations (mg/L) based on available PVWMA and City of Watsonville monitoring well data for 2002-2011. Existing seawater intrusion front mapped by PVWMA based on chloride groundwater quality data (PVWMA, 2011).

### 4.2.1.3 NITRATE-NO<sub>3</sub>

Nitrate-NO<sub>3</sub> groundwater concentration maps were created using 310 monitoring and production well locations and includes 1,718 discrete water quality samples collected by PVWMA and the City of Watsonville from 2002 to 2011. Individual sample nitrate-NO<sub>3</sub> concentrations ranged from a minimum of 0.5 mg/L, which is half the detection limit, to a maximum of 1,830 mg/L, which may indicate the sample was inadvertently collected downstream of a fertigation injection line. The average value obtained from each sampling location was spatially integrated using IDW method to create Figure 4.8 and the decadal maximums were used to create Figure 4.9. Area distribution summaries from both figures are summarized in Table 4.4 below. Results were grouped into four discrete concentration categories:

- Nitrate-NO<sub>3</sub> concentrations <10 mg/L were selected identify locations of relatively minimal nitrate concentrations.
- Nitrate-NO<sub>3</sub> concentrations <45 mg/L meet the safe drinking water standard established by the EPA.
- Nitrate-NO<sub>3</sub> concentrations ranging from 46 – 100 mg/L are considered high and are in excess of the EPA's drinking water standard.
- Nitrate-NO<sub>3</sub> concentration >100 mg/L are considered very high and are significantly above the EPA's drinking water standard.

**Table 4.4:** Percent of PVGB area within concentration range for data in Figures 4.8 and 4.9.

| Nitrate-NO <sub>3</sub><br>Concentration Range | Decadal <b>MEAN</b> NO <sub>3</sub><br>Figure 4.8<br>(% of PVGB) | Decadal <b>MAX</b> NO <sub>3</sub><br>Figure 4.9<br>(% of PVGB) |
|------------------------------------------------|------------------------------------------------------------------|-----------------------------------------------------------------|
| 0.5-10 mg/L                                    | 38%                                                              | 36%                                                             |
| 11 mg/L – 45 mg/L                              | 42%                                                              | 34%                                                             |
| 46 mg/L – 100 mg/L                             | 15%                                                              | 19%                                                             |
| >100 mg/L                                      | 5%                                                               | 11%                                                             |
| Spatially Weighted Concentration*              | 28 mg/L                                                          | 46 mg/L                                                         |

\*Spatially weighted average basin concentration described in Chapter 7.4

Elevated concentrations of nitrate-NO<sub>3</sub> in groundwater tend to be found in agricultural areas overlying sandy soils such as the sand dunes of the San Andreas Terrace, in the eastern area between highways 129 and 152, and south of Corralitos (Figure 4.8). Locations of elevated nitrate-NO<sub>3</sub> concentrations expand when maximum concentration values are displayed (Figure 4.9).

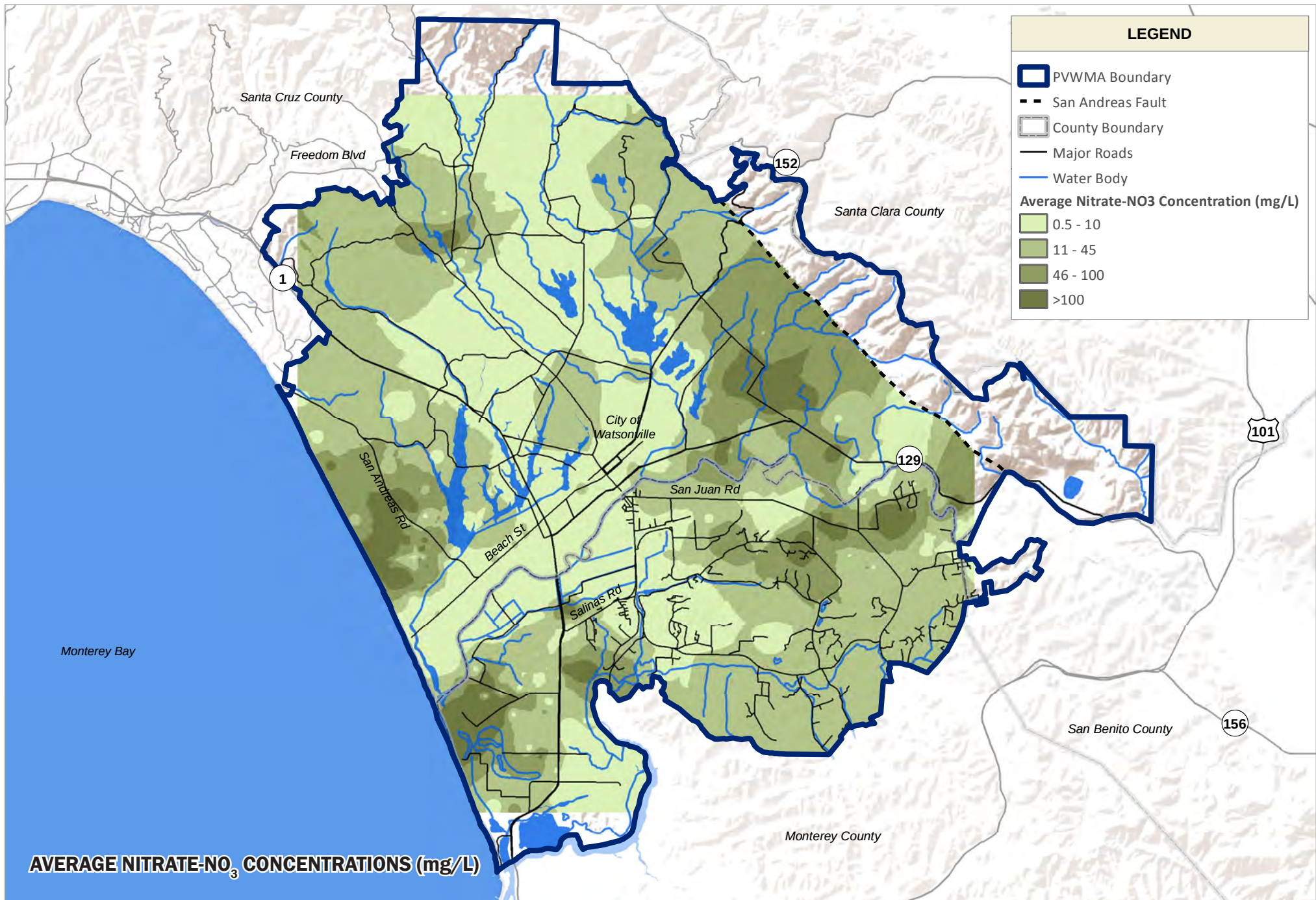


FIGURE 4.8: Interpolated average groundwater nitrate-NO<sub>3</sub> concentrations (mg/L) based on available PVWMA and City of Watsonville monitoring well data for 2002-2011.

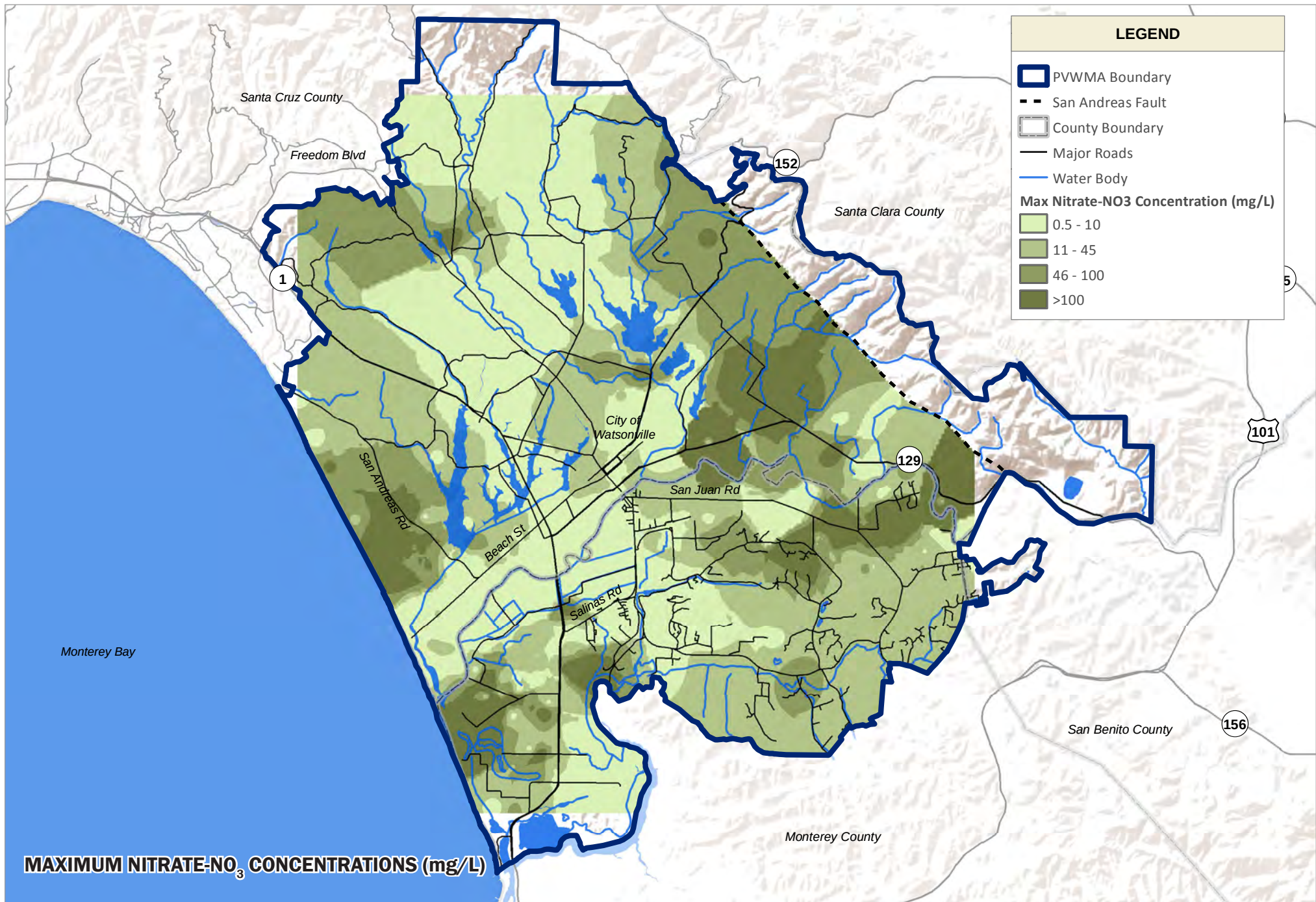


FIGURE 4.9: Interpolated maximum groundwater nitrate-NO<sub>3</sub> concentrations (mg/L) based on available PVWMA and City of Watsonville monitoring well data for 2002-2011.

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### 4.2.2 SURFACE WATER

Surface water provides significant recharge to the PVGB. Recent simulations of the PVHM indicate that approximately 30% of the annual recharge occurs via streamflow infiltration (Table 3.1). The concentrations of salts and nutrients in surface water systems have a high degree of seasonal variability and tend to correlate closely with rainfall and runoff quantity. Since both stream and groundwater quality data vary spatially and temporally, surface water systems may improve or degrade water quality within the basin.

Understanding that surface water quality has a significant impact on groundwater quality, the PVWMA implemented a surface water monitoring program in 1995. For the period of 2002 to 2011, PVWMA monitored 30 sites throughout the basin on a monthly to quarterly frequency (Figure 4.10). As a result, the PVWMA possesses an extensive surface water monitoring dataset that includes sites along the Pajaro River, Corralitos Creek, Carneros Creek, College Lake, Green Valley Creek, Pinto Lake Outflow, Corncob Canyon, as well as the Harkins and Watsonville Slough systems. In addition, various other surface water sampling efforts have been conducted over the years to supplement the existing program and address a variety of questions that range from water quality concerns to inform model development and management decisions.

The PVWMA water quality dataset for the period 2002 to 2011 was queried to provide constituent concentration statistics on a quarterly basis. Surface water concentrations vary significantly by season with high winter flows typically possessing much lower concentrations of salts and nutrients than dry-season base flows. In an effort to document seasonal variation by constituent of concern, the average decadal concentrations by quarter were evaluated for each constituent. For the seasonal comparison, Q1 was selected because it is representative of seasonally low concentrations due to higher flow rates in the streams. In turn, Q3 is representative of seasonally high concentrations resulting from low summer base flow conditions.

An average of 15 data points were used to generate both the Q1 (January 1 – March 31) and Q3 (July 1 – September 30) averages by site for each of the three constituents of concern. Sample results below the analytical detection limit for nitrate-NO<sub>3</sub> of 1 mg/L were common. These samples were assigned a value of 0.5 mg/L so that they could be included in the analysis (Helsel, 2005). Sample results below TDS and chloride analytical detection limits were infrequent and therefore no data adjustments were made.

Figures 4.11 and 4.12 summarize the existing TDS and chloride surface water conditions, respectively, given the spatial distribution of the PVWMA surface water sampling program. Sites in the coastal proximity and downstream of Chittenden Gap on the Pajaro River (PR1, PR2 and PR3) possess relatively higher salt content, particularly during base flow conditions. Approximately 80% of the sites have average surface water TDS concentrations over 450 mg/L in Q3. Surface water systems devoid of significant agricultural influence are expected to have TDS concentrations below 200 mg/L, though natural TDS levels will vary depending upon local geology (SWRCB, 2010).

Figure 4.13 presents Q1 and Q3 average nitrate-NO<sub>3</sub> concentrations, with 17% of sites exceeding 45 mg/L in the winter and 23% exceeding 45 mg/L in the summer. The best water quality is found at sites located in the upper watershed, including Upper Corralitos Creek where the density of potential nutrient sources in the drainage area is relatively low.

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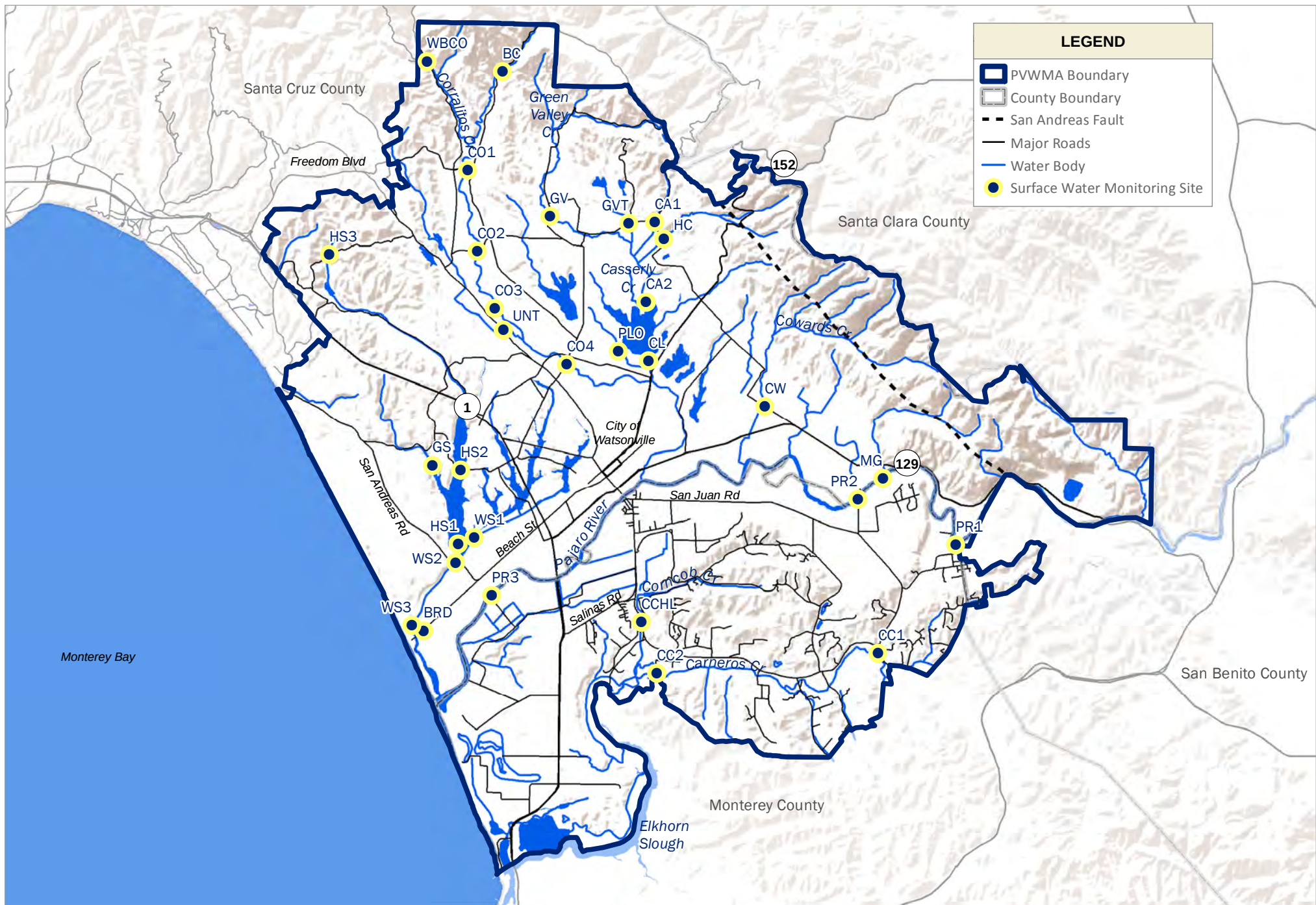


FIGURE 4.10: PVWMA surface water quality monitoring site locations.

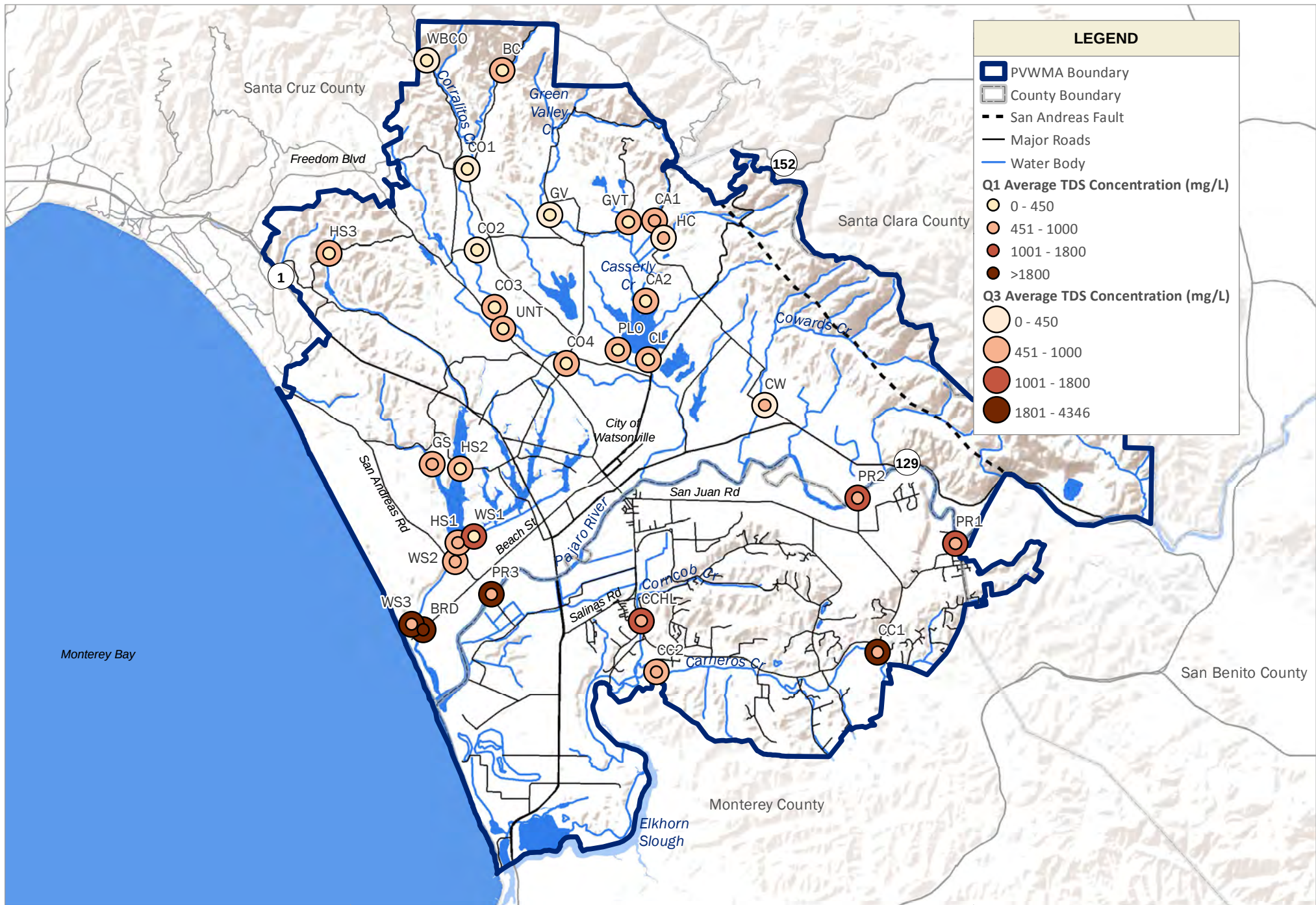


FIGURE 4.11: Quarterly average total dissolved solids (TDS) concentrations (mg/L) based on PVWMA surface water quality monitoring site data between 2002-2011. Q1 (Jan-Mar) represents seasonal minimum concentration values during high flow conditions and Q3 represents seasonal maximum concentration values during base flow conditions.

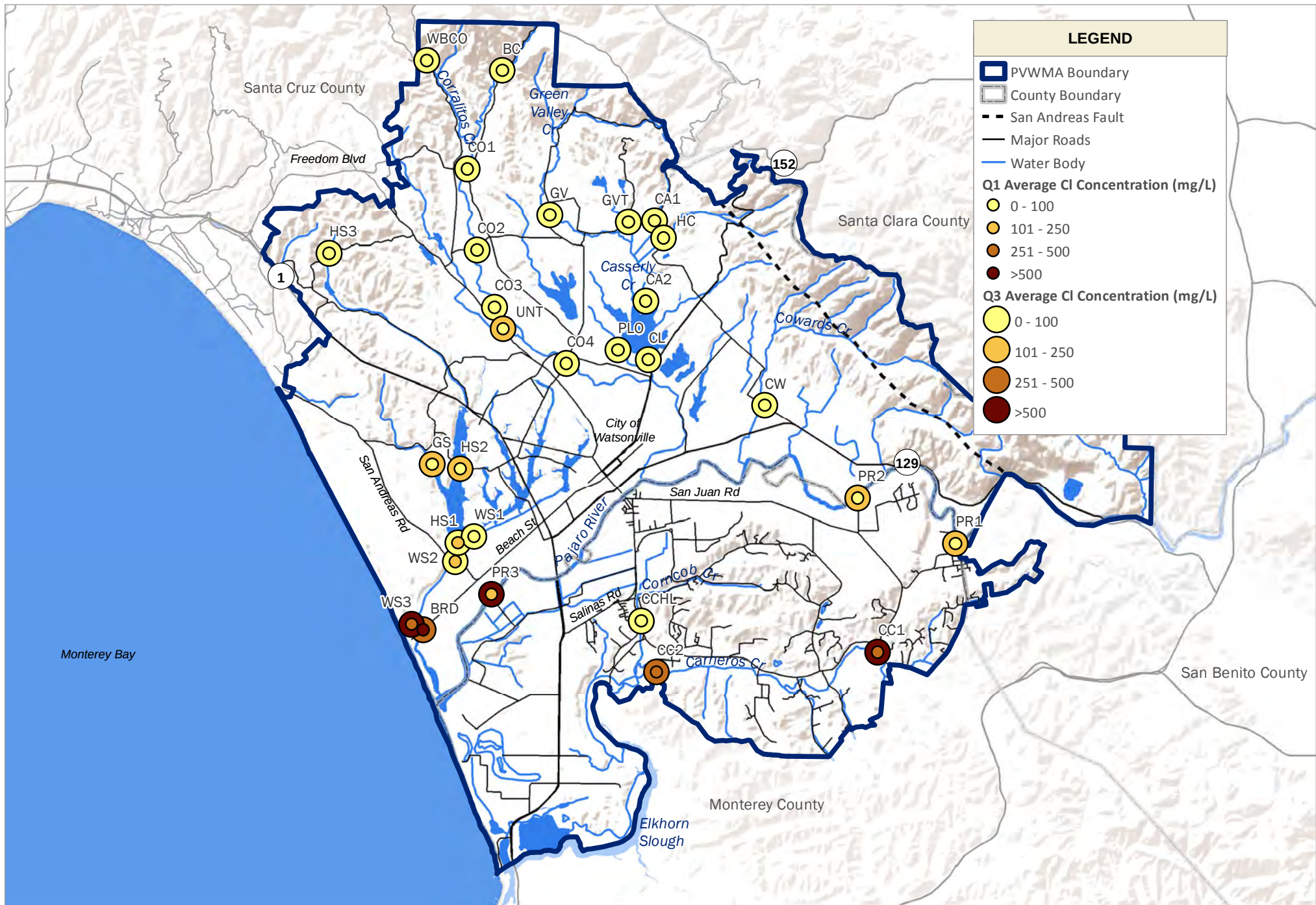


FIGURE 4.12: Quarterly average chloride concentrations (mg/L) based on PVWMA surface water quality monitoring site data between 2002-2011. Q1 (Jan-Mar) represents seasonal minimum concentration values during high flow conditions and Q3 represents seasonal maximum concentration values during base flow conditions.

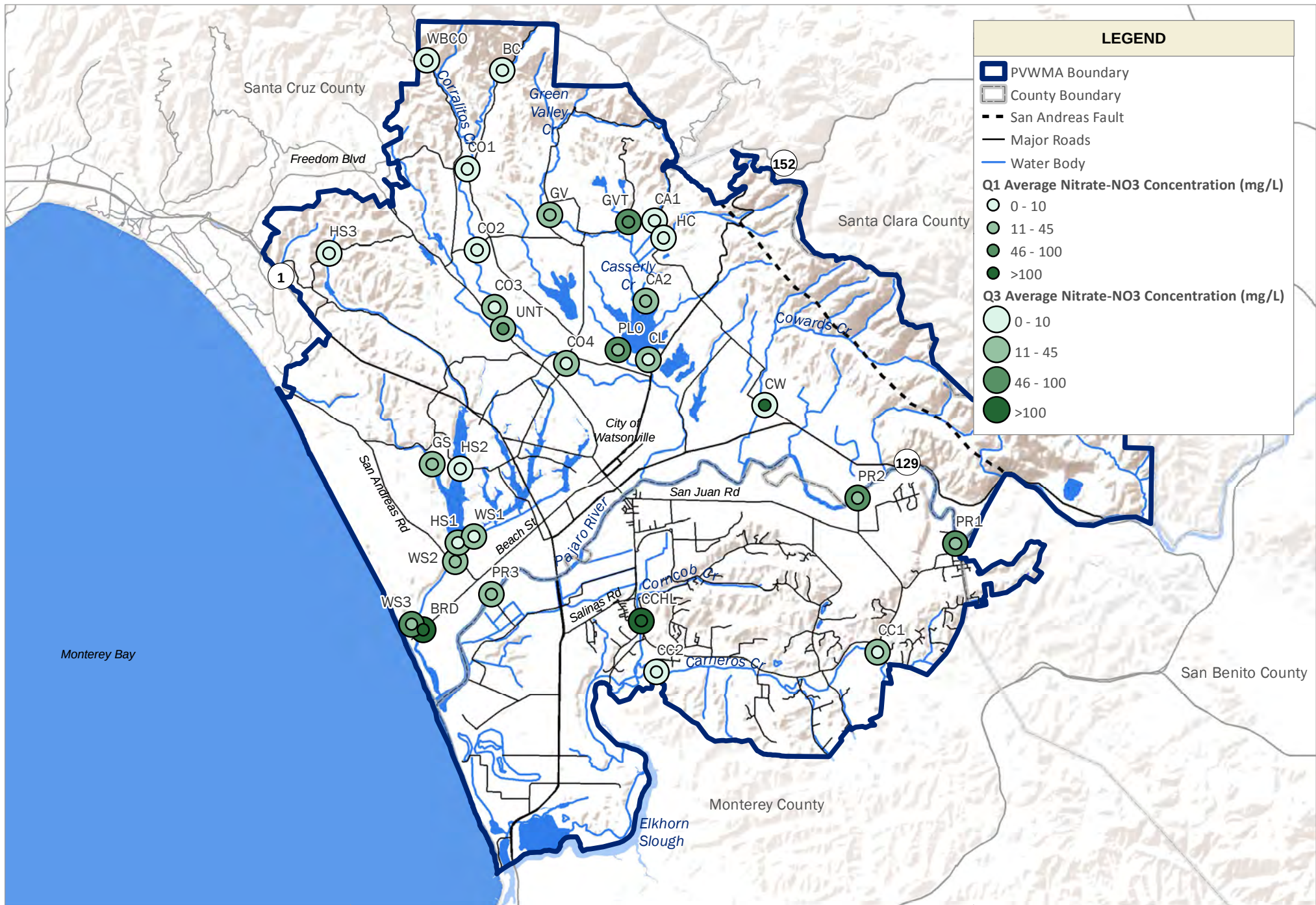
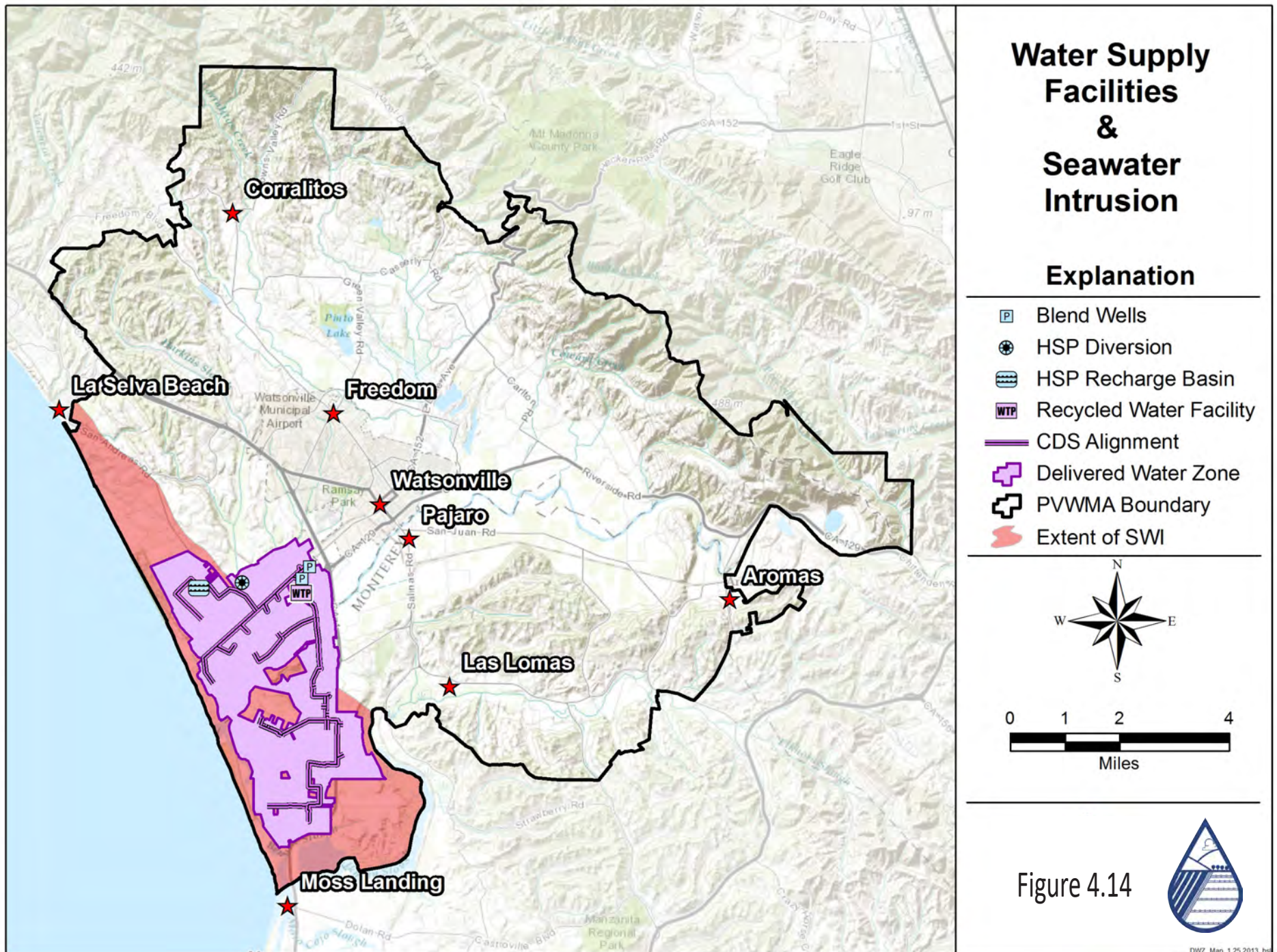


FIGURE 4.13: Quarterly average nitrate-NO<sub>3</sub> concentrations (mg/L) based on PVWMA surface water quality monitoring site data between 2002-2011. Q1 (Jan-Mar) represents seasonal minimum concentration values during high flow conditions and Q3 represents seasonal maximum concentration values during base flow conditions.

### 4.3 Delivered Water Quality

As part of the implementation of the Basin Management Plan, the PVWMA has constructed several water supply facilities and over 20 miles of underground distribution pipeline in an effort to reduce coastal groundwater pumping in order to stop seawater intrusion and eliminate groundwater overdraft. Water delivered via the Coastal Distribution System (CDS) is used for agricultural irrigation supply instead of groundwater, and as such serves as in-lieu recharge. The area served by the CDS is known as the Delivered Water Zone (DWZ); consisting of more than 7,600 acres, this area is shown in Figure 4.14. PVWMA staff closely monitor the volume and quality of delivered water supplies, which is composed of the following sources: disinfected, tertiary treated, recycled water; City of Watsonville potable water; water recovered from the Harkins Slough Managed Aquifer Recharge (MAR) and Recover Facility; and additional supply from PVWMA blended wells. Since 2009 when recycled water deliveries began, 560 water quality samples have been collected from active turnouts distributed throughout the distribution system. Though water quality varies, the average concentration of water distributed to the DWZ for each constituent of concern is TDS 612 mg/L, chloride 104 mg/L, and nitrate-NO<sub>3</sub> 27 mg/L. The delivered water quality is compared to the existing groundwater conditions within the DWZ in Table 10.1.



## 5 SALT AND NUTRIENT LOADING ANALYSIS

A key element of the SNMP, as required by the State Water Resources Control Board (Water Board), is a salt and nutrient loading analysis that identifies primary sources of salts and nutrients and estimates their relative loading to the local groundwater basin. The Water Board does not specify the manner in which the salt and nutrient loading analysis should be completed, leaving the identification of an appropriate approach and analysis to the personnel working in each basin, with input from stakeholders. The loading analysis presented below uses a data driven approach to generate relative loading potential and quantitative loading estimates to groundwater.

A primary goal of the loading analysis conducted herein is to provide guidance to the local stakeholders on the relative risk salt and nutrient loading to groundwater via different loading pathways. By understanding the relative source contributions, projects and/or programs can be developed to most effectively reduce annual loads of salts and nutrients to groundwater. The approach undertaken for this SNMP identifies the critical pathways expected to be most influential in salt and nutrient loading to groundwater, and provides quantitative loading estimates. The loading analysis relies heavily on existing water quality, land use mapping, hydrologic modeling results, and other available local datasets. Specifically, the methodology for nutrient loading closely follows detailed assessments that have been applied in nearby Tulare and Salinas Valley groundwater basins by Viers *et al.* (2012). A desired outcome of this approach is that the methods are transparent and the graphics communicate key concepts to a broad range of stakeholders.

The approach to estimating salt and nutrient loading aligns with our technical understanding of system dynamics and primary pathways to groundwater loading, as well as meets the requirements outlined in an informational document distributed by the CCRWQCB via a March 3, 2014 letter. These products inform SNMP objective development and identification of management strategies that address sources of the constituents of concern.

### 5.1 Loading Pathways to Groundwater

In order to conduct a loading analysis, it is critical to understand the primary pathways in which salts and nutrients are transported into the PVGB. The PVHM (Hanson *et al.*, 2014) quantifies the relative hydrologic inputs to the PVGB, each with different mechanisms of transport and management implications. The following chapter discusses the ways in which seawater intrusion, surface water infiltration, and streamflow infiltration influences loading to groundwater in the PVGB.

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#### 5.1.1 SEAWATER INTRUSION

Seawater intrusion may occur in a coastal basin when groundwater pumping reduces pressure gradients that historically, or pre-development, caused groundwater to flow from the basin into the ocean. When the potentiometric surface of groundwater approaches mean sea level, or falls below, the higher density of seawater will cause it to flow into the adjacent aquifer. Under natural or pre-development conditions, the groundwater pressure gradients would cause freshwater to flow toward the ocean, usually resulting in the discharge of freshwater to the sea. When pressure gradients are reduced either locally (i.e., a well located close to the coast) or regionally via long-term groundwater overdraft resulting in groundwater storage depletion and the lowering of groundwater surface

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elevations, seawater may flow into a fresh water aquifer. Groundwater pumping regimes have the ability to shift the equilibrium. In general, the further inland groundwater levels fall, the less pressure that is exerted on the intruding seawater, potentially resulting in increased rates of seawater intrusion.

As seawater flows into a groundwater basin, the quality of water in the aquifer is degraded. Seawater has an average TDS concentration of 35,000 mg/L and an average chloride concentration of 19,000 mg/L, far exceeding the Central Coast Water Quality Basin Plan objectives of 1,000 mg/L and 150 mg/L for TDS and chloride, respectively. Increasing chloride levels are problematic for all water uses, especially agriculture. Salt sensitive crops may be impacted with TDS concentrations exceeding 500 mg/L (SWRCB, 2010). The degraded water quality caused by seawater intrusion has resulted in the widespread abandonment of groundwater wells in many coastal locations throughout the country (Barlow, 2010), including some within the Pajaro Valley.

Seawater intrusion resulting from groundwater overdraft has been extensively documented in the BMP (PVWMA, 2014). The cumulative overdraft of the PVGB has caused groundwater elevations to fall and remain below mean sea level year round in parts of the basin (Figure 2.3). Chapter 2 of the BMP (pg. 16-18) describes the historical and current groundwater levels (see BMP figures 2-8 to 2-13). During periods of drought, the area expands, while during wet periods, the area contracts. In 2012, approximately 31,300 acres (or 43%) of groundwater surface elevations within the PVGB were at or below mean sea level. PVWMA has used a groundwater chloride concentration greater than or equal to 100 mg/L to indicate the inland extent of intruding seawater. Using a groundwater chloride concentration dataset from 1951-2011, PVWMA has tracked the rates of seawater intrusion within the PVGB (Figure 5.1). Many of the coastal wells have had large increases in chloride concentrations over the past six decades. The elevated chloride concentrations along the coast and the extent of the seawater intrusion front are illustrated in Figure 4.6. While the hydrogeology of the groundwater basin is complex, seawater intrusion will generally continue to migrate inland if groundwater levels remain below protective elevations (PVWMA, 2014). Quantitative estimates of salt loading and relative loading potential of seawater intrusion are assessed in Chapter 5.2.

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### 5.1.2 SURFACE WATER INFILTRATION

The PVHM identifies surface water infiltration as the largest input to the PVGB, at an annual average of 31,320 AFY (Table 3.1) between 2005 and 2009. Prior research, listed below, has identified locations where groundwater recharge to the local aquifers occur. A thorough effort was conducted to compile a plethora of available data sources documenting the locations and relative rate of recharge. These data sources were strategically integrated to create the best available spatial representation of the relative potential for groundwater recharge. The individual recharge layers are mapped in Figures 5.2 through 5.6 and are described in more detail in the subsequent sections. A list of the sources and the associated maps include:

- Natural Resources Conservation Service (NRCS) relative water holding capacity soils (Figure 5.2)
  - Recharge zones from SC County (Figure 5.3)
  - Recharge zones from a 1984 study by Barry Hecht (Hecht. B., 1984) (Figure 5.4)
  - Adaptation of Russo *et al.* (2013) for determination of relative groundwater recharge potential (Figure 5.5)
  - Weighted integration adaptation of Russo *et al.* (2013) (Figure 5.6)
-

# Seawater Intrusion within the Pajaro Valley

## Explanation

- ★ Cities & Towns
- ⬢ PVWMA Boundary
- Extent of SWI as of 1951\*
- Extent of SWI as of 1966\*
- Extent of SWI as of 1998\*
- Extent of SWI as of 2011\*

\*Chloride contours are set to concentrations of 100 mg/L



Figure 5.1



Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, and the GIS User Community

In the next section, these data sources are explained in detail and are integrated to produce a basin-wide groundwater recharge potential map (Figure 5.8).

### 5.1.2.1 NRCS SOIL WATER HOLDING CAPACITY

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The relative water holding capacity of soil in the unsaturated zone, controls the rate at which water can infiltrate a soil horizon and is a critical factor in determining the likelihood of dissolved constituents derived from land use practices reaching shallow groundwater. A linear regression model created by Nolan *et al.* (2002) predicts (with 75% confidence) the likelihood that recently recharged shallow groundwater aquifers within the U.S. possess elevated nitrate levels and found the relationship to be highly sensitive to land use (both urban and agriculture) and distribution of well-drained soil types. Generally, the likelihood of nutrients leaching vertically from the unsaturated zone into shallow groundwater is greater in locations of low soil water holding capacities. However, depth to shallow groundwater, subsurface hydrogeology and stratigraphy, and localized heterogeneities will greatly influence the actual hydrologic connection between dissolved constituents introduced to surface soils and the subsurface aquifer. Consequently, soil water holding capacity is just one of many variables that will contribute to the more complete understanding of groundwater recharge potential.

Water holding capacity categories were based on discrete soil types and on the soil's ability to hold the potential irrigation volumes applied to crops grown in the Pajaro Valley. The water holding capacity of the soil is dependent on a number of factors including clay content, compaction, drainage, and slope. The NRCS maps (SSURGO 2009) classify soils and provide data on the water holding capacity, drainage class, and slope. The NRCS database defines water holding capacities vertically in the soil: 0-25 cm, 0-50 cm and 0-100 cm. The NRCS water holding capacity was averaged over 0-100 cm and then separated into 4 relative categories from low to high. The relative water soil holding capacity distribution within the PVGB is presented in Figure 5.2 based on the following categories:

**Low:** Water holding capacity defined as 0 – 8.9 inches (0 – 22 cm) of water per meter of soil profile, equating to a retention range of 0 to 0.75 acre feet (AF) of water applied per acre per year. These soils are characterized as relatively unconsolidated with high sand and low organic content, located near the coast and the steepest slopes above the river bottom. These soil types are expected to be most susceptible to vertical leaching within the basin.

**Moderate:** Water holding capacity defined as 9 – 14.9 inches (23 – 38 cm) of water per meter of soil profile, equating to a retention range of 0.75 – 1.25 AF /acre/yr. These soils include the silty/sand loams on various slopes.

**High:** Water holding capacity of 15 – 17.9 inches (38 – 45 cm) of water per meter of soil profile, or 1.25 – 1.5 AF/acre/yr. These soils include finer silty/sand loams.

**Very high:** Water holding capacity of 18 – 28 inches (46 – 71 cm) of water per meter of vertical soil profile per year; or 1.5 – 2.3 AF/acre/yr. These soils are predominantly clays as indicated by the extensive deposit along the historic Pajaro River floodplain. These soil types are expected to be least susceptible to vertical salt and nutrient leaching.

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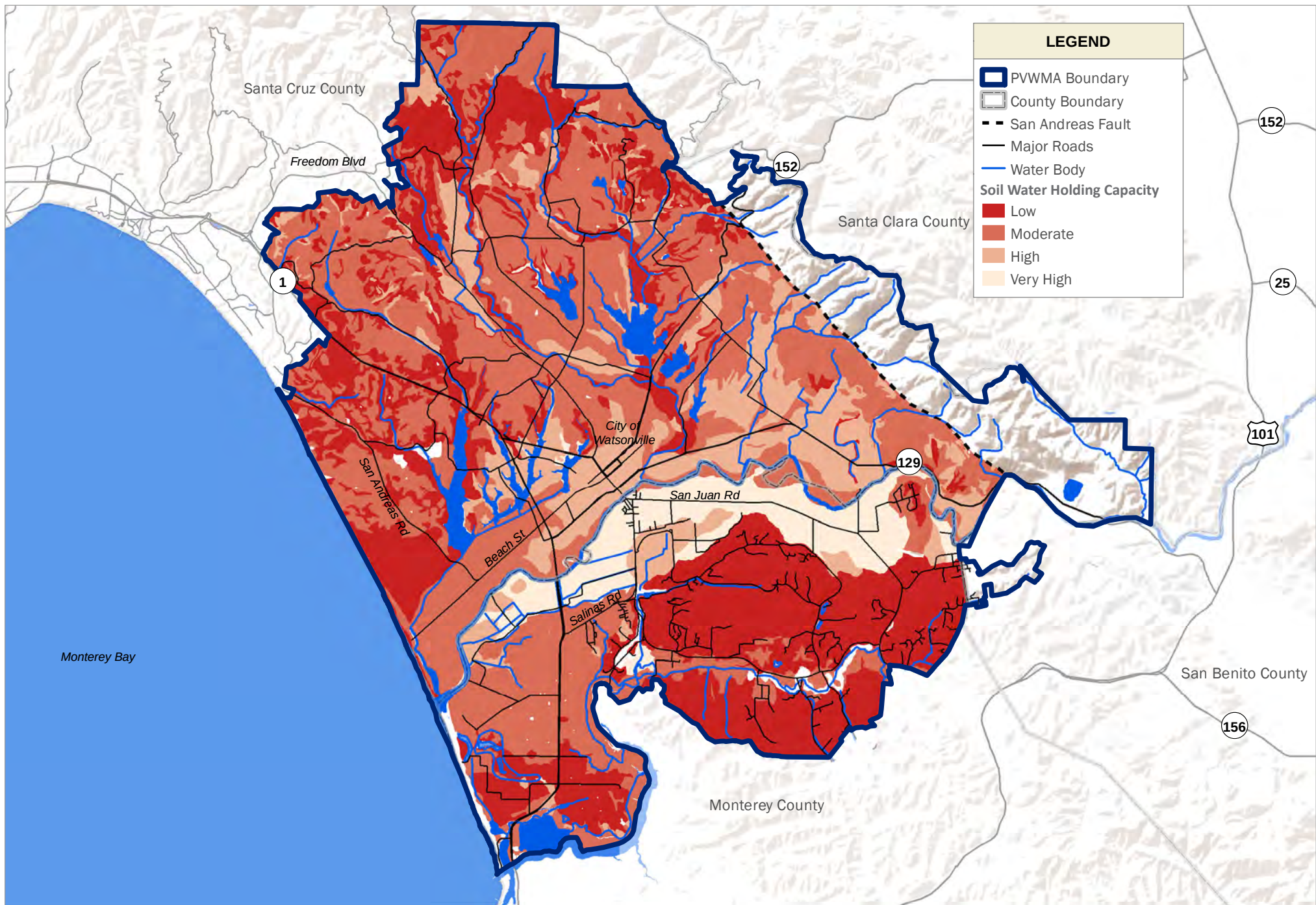


FIGURE 5.2: Relative soil water holding capacity based on NRCS soil survey geographic data (SSURGO, 2009).

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### 5.1.2.2 PAST RECHARGE MAPPING

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The County of Santa Cruz has generated a county wide groundwater recharge map that is available for download from ([http://gis.co.santa-cruz.ca.us/file\\_download\\_site/](http://gis.co.santa-cruz.ca.us/file_download_site/)) and these mapped zones within the PVWMA area are presented in Figure 5.3. In addition, Barry Hecht and HEA Consultants conducted a detailed geologic assessment of the PVWMA area in 1984 and the results of their mapping are presented in Figure 5.4. Soil water holding capacity, SC County, and the Hecht recharge data were used to supplement relative recharge potential in locations where the Managed Aquifer Recharge Suitability Study (Russo *et al.* 2013) did not have data (Chapter 5.1.2.4).

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### 5.1.2.3 RELATIVE EXPOSURE TO SHALLOW GROUNDWATER

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A Managed Aquifer Recharge (MAR) Suitability Study was conducted by Russo *et al.* (2013) to identify locations within the Pajaro Valley where recharge opportunities exist to implement localized groundwater recharge projects that would reduce groundwater overdraft. All of the raw data layers and categorical definitions were obtained directly from Russo. The attributes and relative weighting were preserved from the Russo's work (Figure 5.5) and the depth to groundwater, based on available recent PVWMA data, was integrated into the final determination of groundwater loading potential displayed as Figure 5.6. Areas of high recharge potential are located on the coast north of the Pajaro River outlet to the ocean, the hills to the southwest of Aromas, and the upper reaches of the Pajaro River and Corralitos Creek. As Figure 5.6 displays, the final coverage of the map was limited by the extent of the available datasets, which did not include the complete PVWMA area.

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### 5.1.2.4 GROUNDWATER RECHARGE POTENTIAL

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The purpose of the groundwater recharge potential map is to delineate areas ranging from high to low relative recharge potential. Areas with low recharge potential have a low risk that salts and nutrients from surface water, irrigation water, or seawater will reach groundwater. Areas with high recharge potential may be more likely to have salts and nutrients from surface water and irrigation water reach shallow groundwater. Figures 5.2 through 5.6 were combined in order to create an integrated groundwater recharge potential map from the best available data for the PVGB.

The work of Russo *et al.* (2013) provided the basis for the groundwater recharge potential map (Figure 5.5) and includes a variety of hydrogeologic parameters specific to the PVGB. This map alone would typically be sufficient to use for the remainder of the loading analysis except that key regions in the north, south, and western portions of the PVGB did not have data. Thus, the information displayed in Figures 5.2 through 5.4 was leveraged to fill in the boundary data gaps following the Russo *et al.* (2013) approach. Figure 5.7 shows the data used in the integration process and Figure 5.8 displays the completed groundwater recharge potential map. The final relative recharge potential includes a three component categorization and the area distribution for each of the three categories is provided in Table 5.1.

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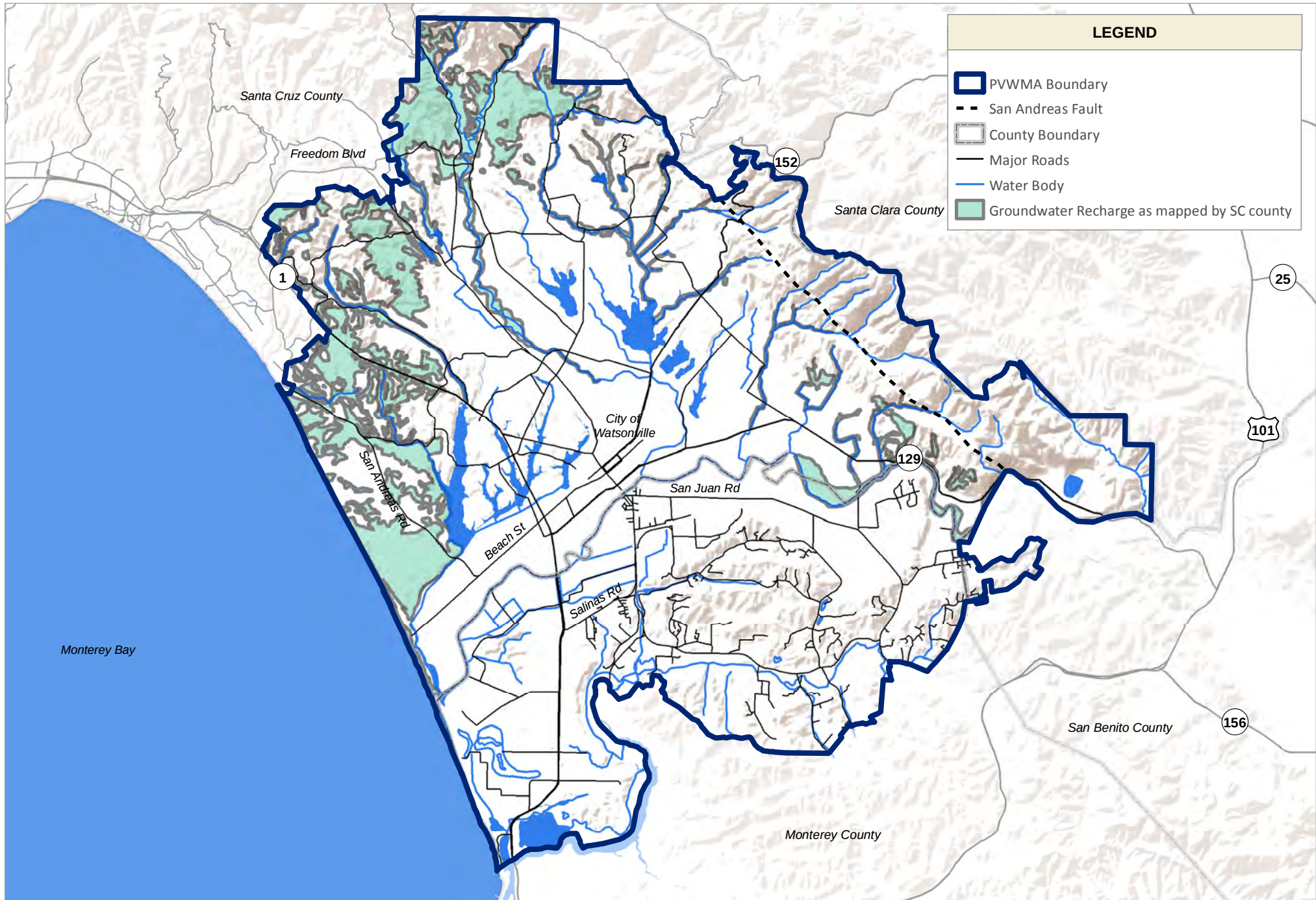


FIGURE 5.3 Recharge zones within the PVWMA boundaries as downloaded on 8/7/2014 from the SC County GIS file download site. Recharge zones were certified by a geologist or hydrogeologist and digitized by the county's environmental health staff.

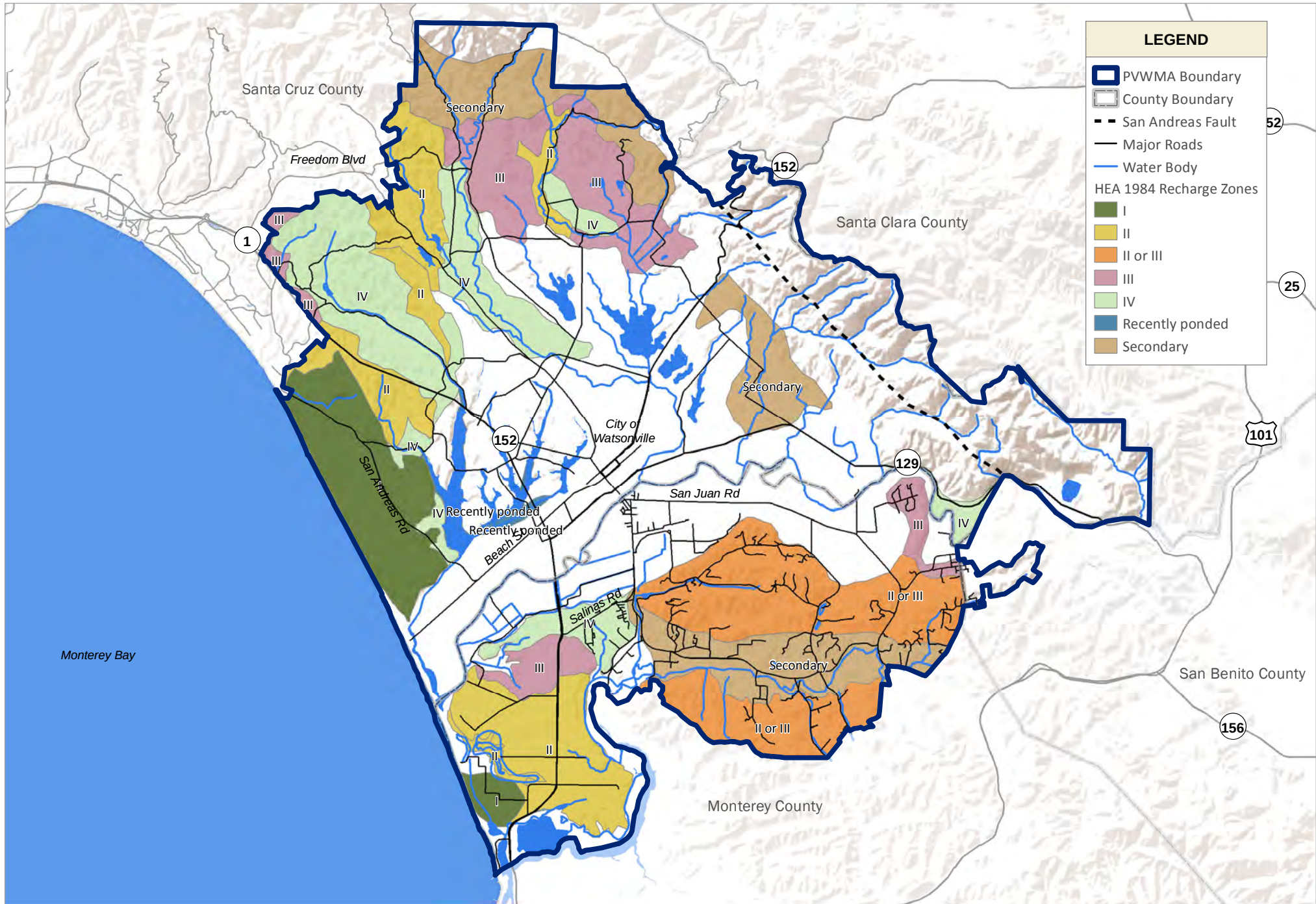
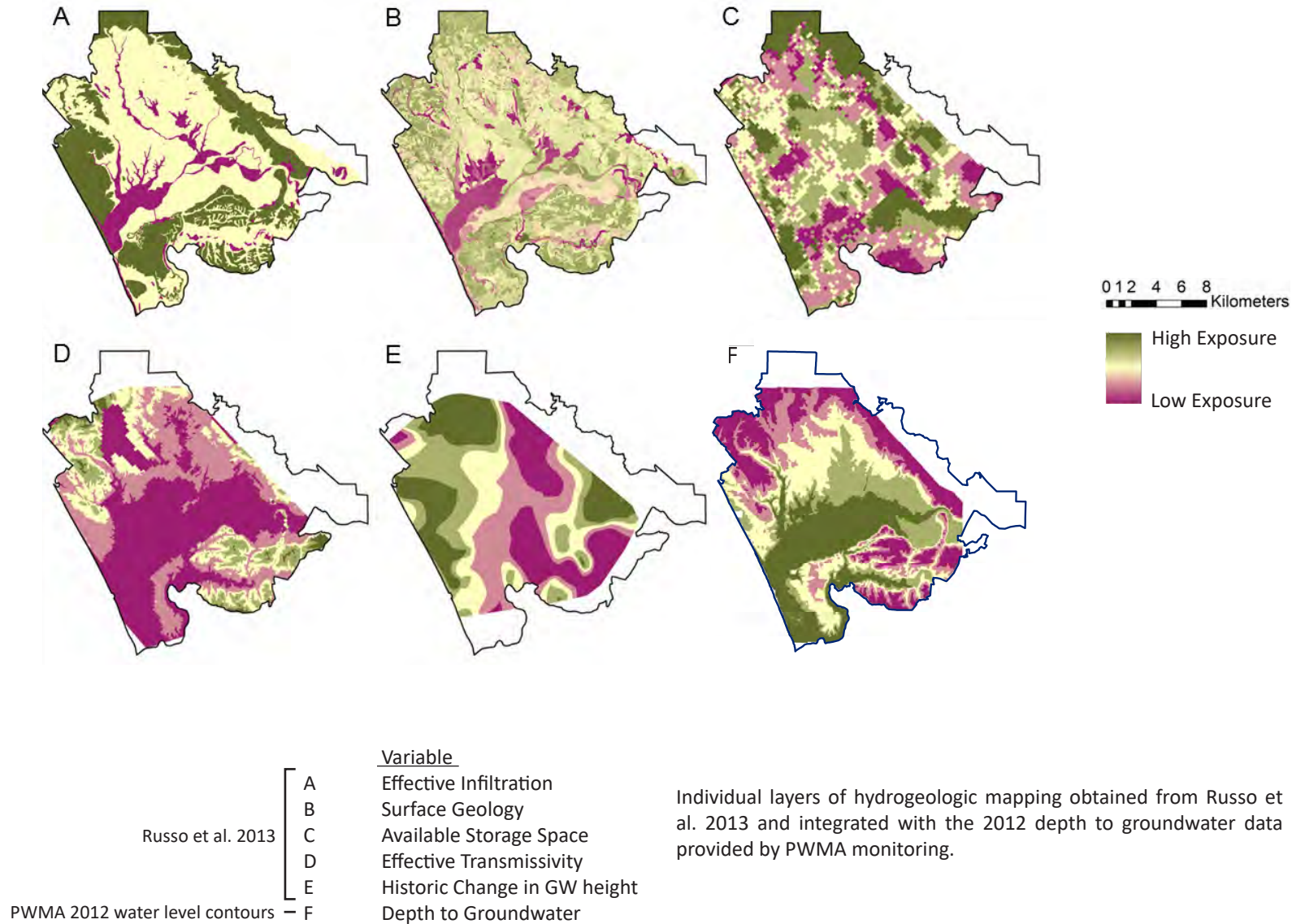
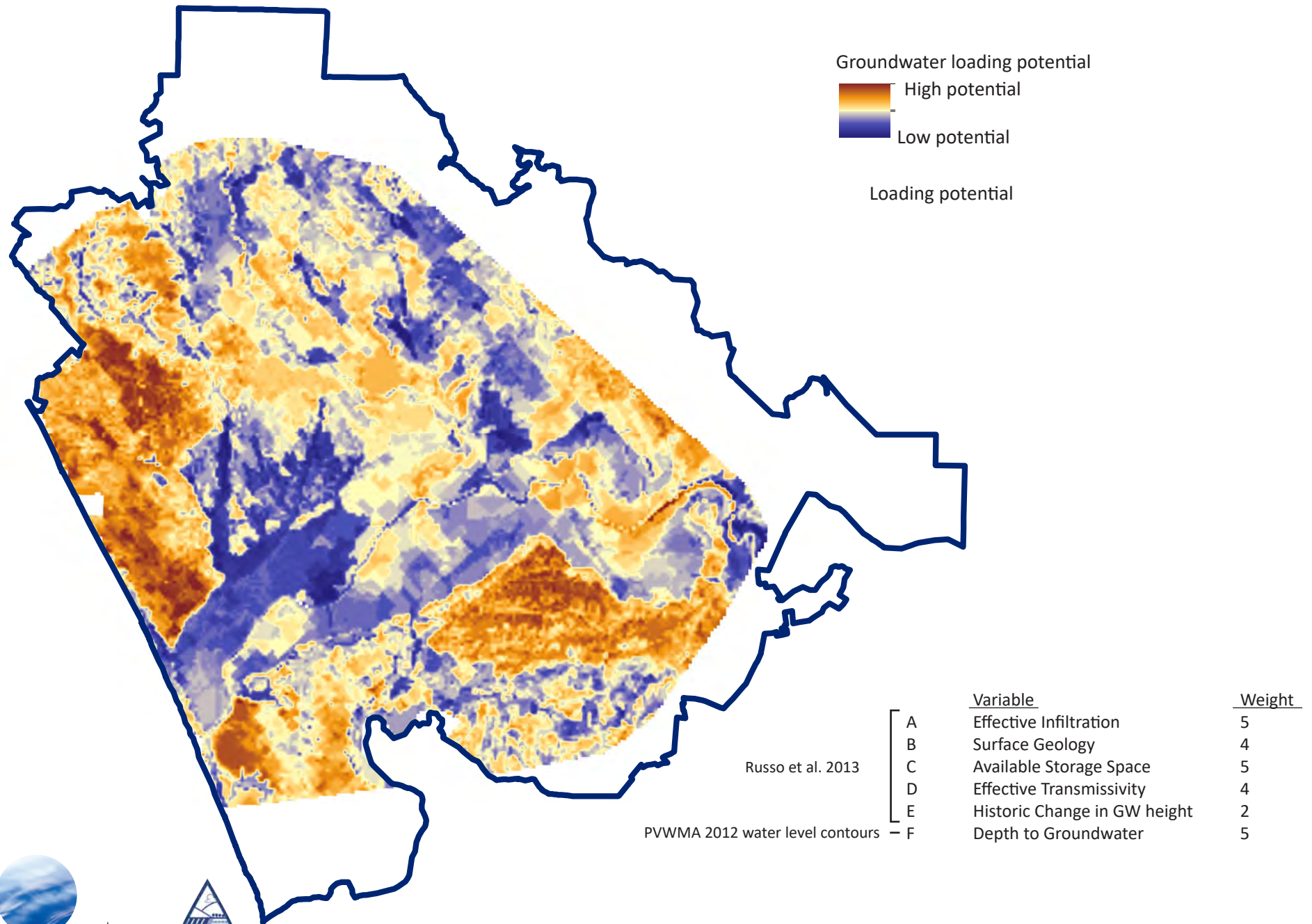


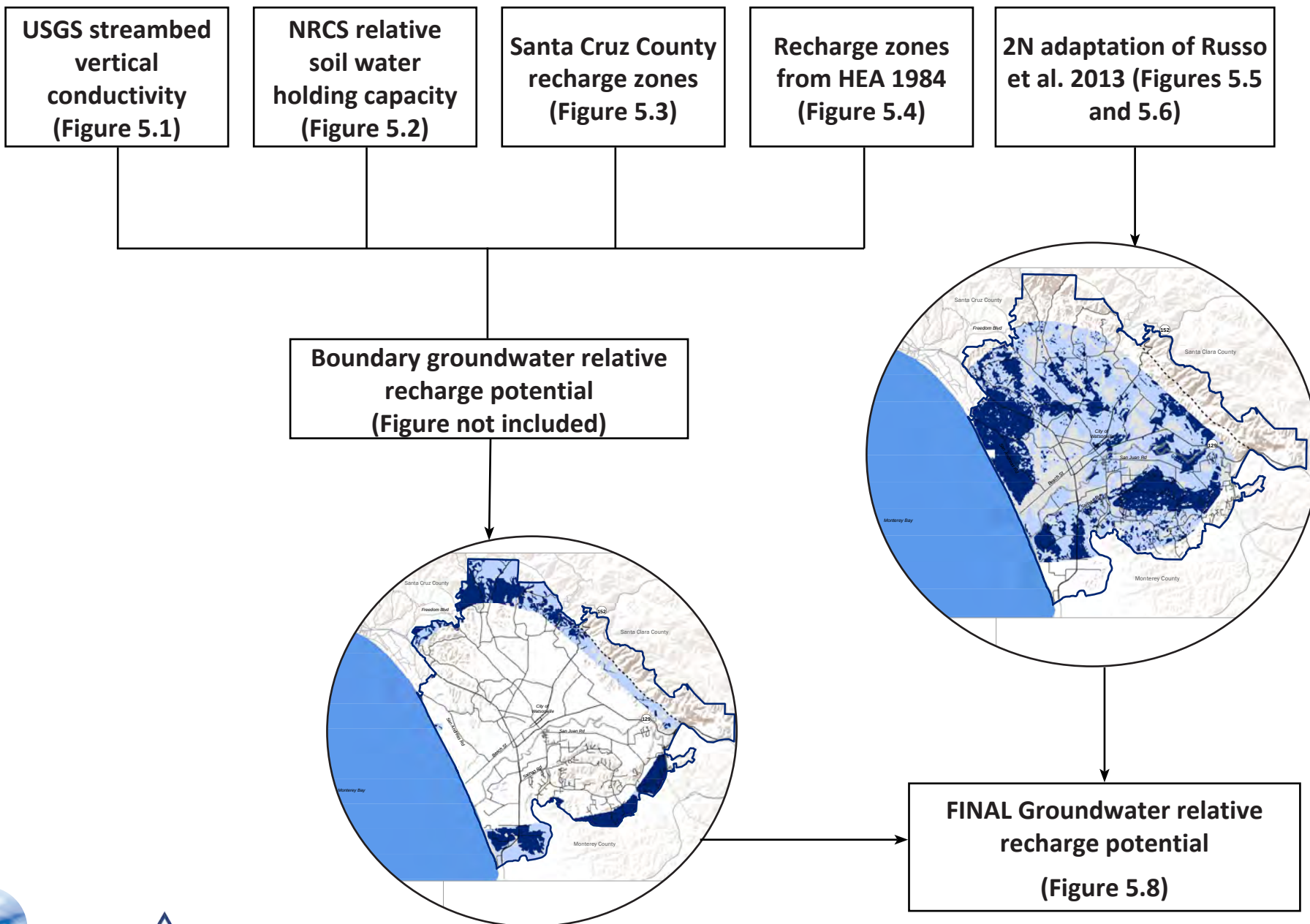
FIGURE 5.4 Recharge zones designated by Barry Hecht. The categories are based on relative annual recharge listed in decreasing order in legend (Hecht, b., 1984).

Spatial display of hydrogeologic variables assumed to influence the relative recharge potential from the land surface to the shallowest groundwater table.



Resulting groundwater recharge potential map following the weighted spatial integration of the the hydrologic variables listed below and displayed on Figure 5.5.





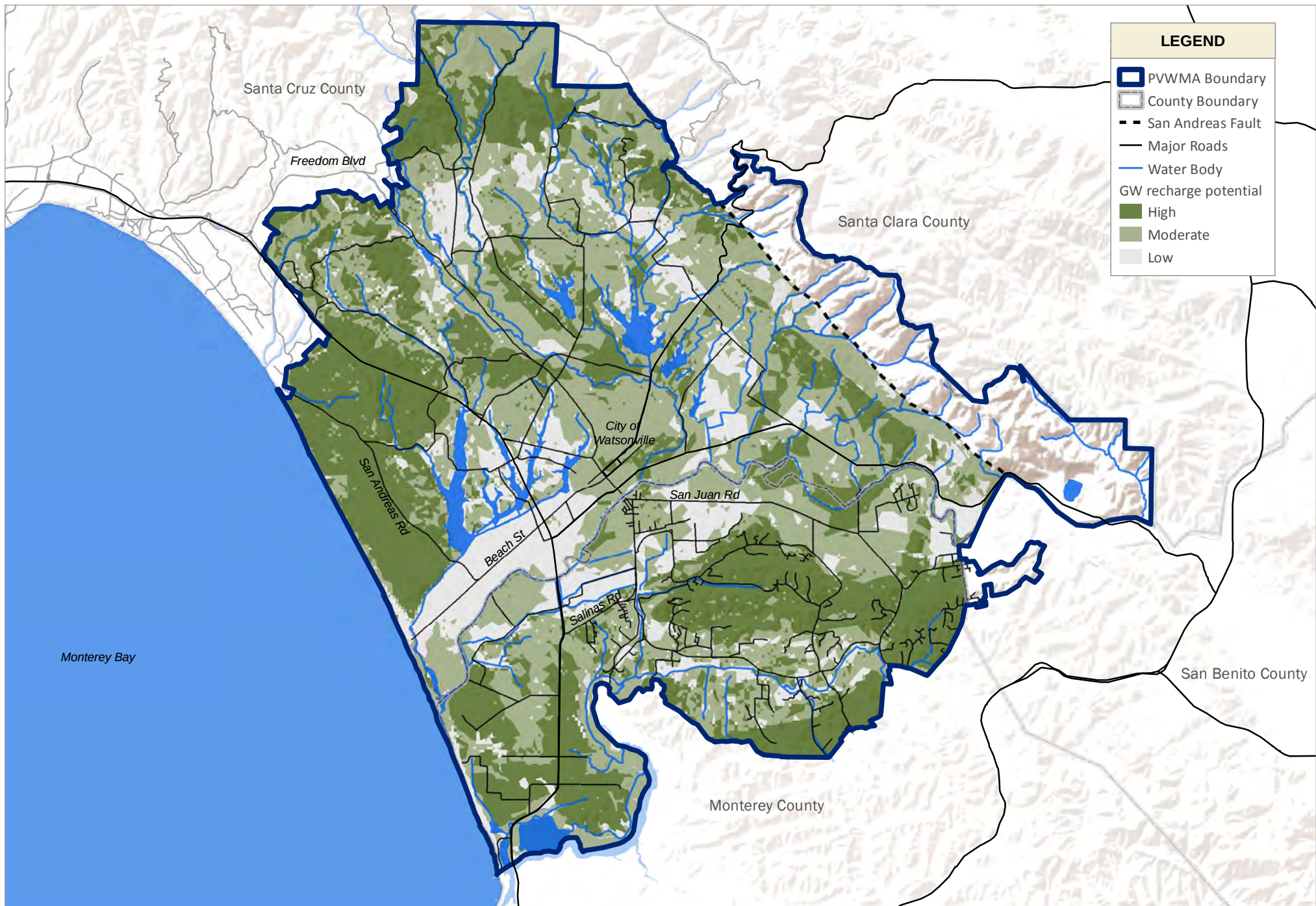


**FIGURE 5.8: Relative groundwater recharge potential for PVWMA based on the integration of available datasets as outlined in Figure 5.7.**

**Table 5.1:** Area distribution of groundwater recharge potential from surface infiltration from Figure 5.8.

| GW Recharge Potential | Area Distribution (acres; %) |
|-----------------------|------------------------------|
| <b>HIGH</b>           | 26,050; 36%                  |
| <b>MOD</b>            | 31,750; 44%                  |
| <b>LOW</b>            | 13,720; 19%                  |

The final integrated map (Figure 5.8) shows high relative recharge occurring in the area along San Andreas Road in the northwestern portion of the PVGB as well as in the surrounding areas of Corralitos and Las Lomas. High relative recharge zones are also located along the bed of the Pajaro River at Chittenden Gap where HWY 129 enters the basin, which is likely due to the very high permeability of the channel bed material in this location. The spatial distribution of primary recharge zones generally aligns with the location of the low water holding capacity soils, providing additional evidence in support of the critical role soil properties play in constituent loading to groundwater.

### 5.1.3 STREAMFLOW RECHARGE

Streamflow within the Pajaro Valley originates from two sources: runoff from within the valley in the many tributaries to the Pajaro River or Carneros Creek, or, streamflow from outside of the Pajaro Valley that enters the PVGB near Chittenden Gap. A number of studies have looked at the flux of discharge on various stream reaches within the PVGB as a result of gains and losses due to infiltration to the groundwater aquifer. Some reaches of the Pajaro River can lose up to 7-14 CFS (0.2-0.4 m<sup>3</sup>/s) of discharge as a result of streambed seepage, contributing to a large portion of the annual aquifer recharge (Ruehl *et al.*, 2006). Surface water within the PVGB was modeled using the Streamflow Routing Package within the PVHM, which incorporated stream gaging data, volumes, and hydraulic conductance of each stream segment (Hanson *et al.*, 2014). The PVHM groundwater budget for the period between 2005 and 2009 simulated that streamflow recharge is the second largest input of water into the PVGB with an estimated 14,960 AFY over the 5-year period (Table 3.1). A stream-bed vertical conductivity classification based on field measurements conducted by the University of California, Santa Cruz, and on PVHM parameters, which also used this data, is shown in Figure 5.9. The dark blue reaches are where groundwater recharge occurs at a greater rate, notably the Pajaro River between Chittenden Gap and Murphy Crossing, and reaches located on Corralitos Creek. It is understood that these reaches are frequently net losing streams (Hecht *et al.*, 2010). The high stream-bed vertical conductivity in these locations facilitates significant recharge to the groundwater basin. The quality of the in-stream water varies seasonally and has the potential to be high in salts and / or nutrients, particularly during the dry half of the year (Reuhl *et al.*, 2007).

## 5.2 Salt Loading Potential

The salt loading analysis conducted for the SNMP evaluates the expected average annual loading of salt to groundwater throughout the Basin. The two constituents included in this analysis are TDS and chloride. TDS serves as a simple proxy for the bulk salt content of water while chloride is useful as an indicator of seawater intrusion. The primary sources and associated concentrations of salt loading to groundwater include:

- Seawater intrusion at the coast (> 1000 mg/L TDS and >150 mg/L chloride)
- Irrigation practices, particularly with waters containing elevated salts (>1000 mg/L TDS)

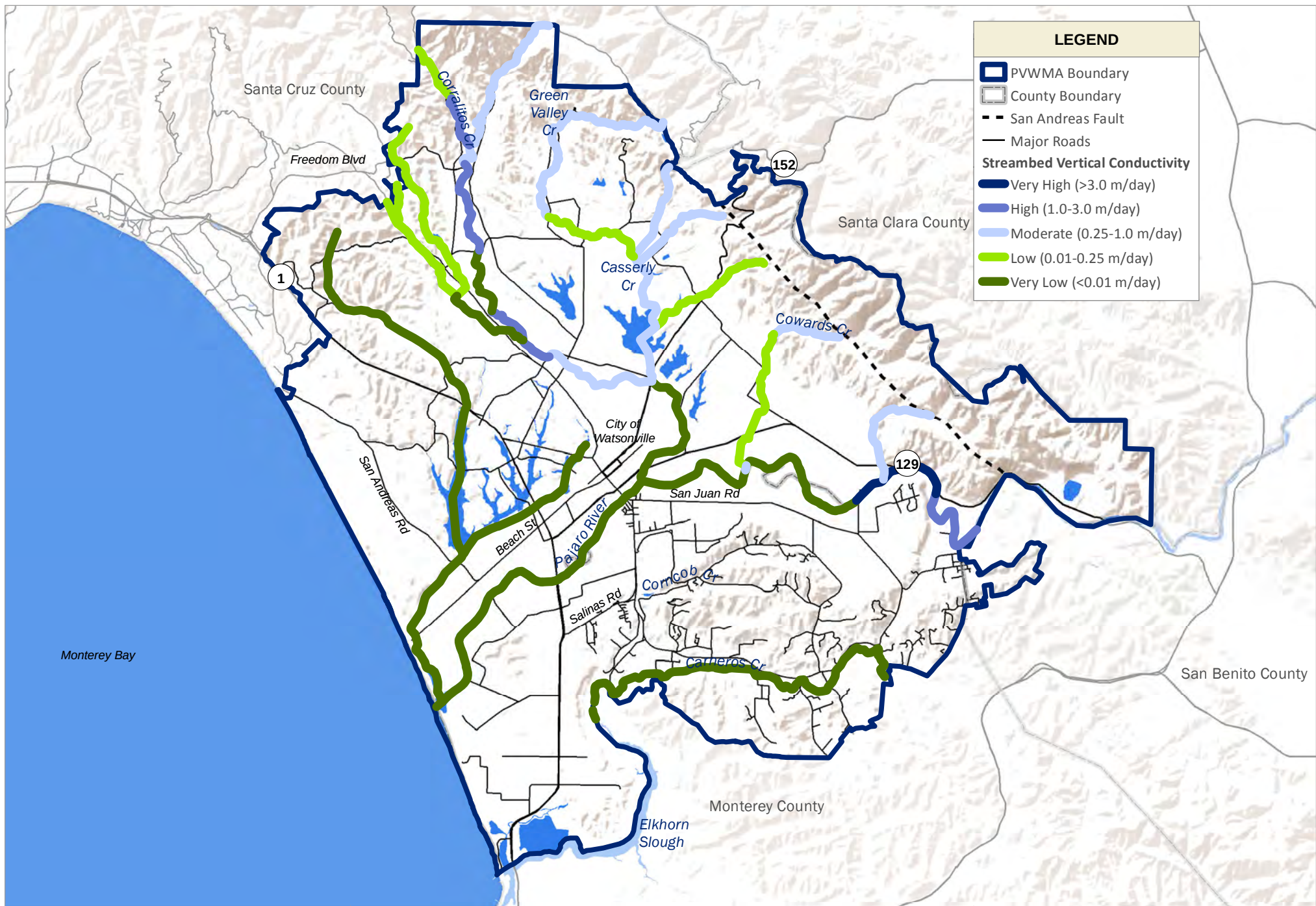


FIGURE 5.9: Relative stream-bed vertical conductivity for major PVWMA streams created based on PVHM parameters and field measurements conducted by the University of California, Santa Cruz.

- Streamflow recharge of water with elevated salts (>1000 mg/L TDS)

Locations of relatively high source contributions of salts as well as estimates of total loading to the PVGB are provided below.

### 5.2.1 SEAWATER INTRUSION LOADING POTENTIAL

The rate and inland extent of seawater intrusion is linked with the balance between groundwater extraction rates and annual recharge. This is substantiated by recent simulations (R.T. Hanson, USGS, written communication, July, 2015), which provide estimates of the volume of storage depletion caused by seawater intrusion (via the contamination of otherwise good quality water). The average estimate was 2,550 AFY during the model period for water year 2005-2009, with only 1,470 AFY estimated during wet year of 2006. Given the known chloride and TDS concentration of seawater and multiplying by the volume of intruding seawater we provide an estimate of the chloride and TDS loading to the aquifer due to seawater intrusion (Table 5.2).

**Table 5.2:** Loading estimates of short tons of chloride and TDS resulting from seawater intrusion as simulated by the PVHM

| Time Period | AFY  | Chloride tons/year | TDS tons/year |
|-------------|------|--------------------|---------------|
| 2008 (Dry)  | 2670 | 68,876             | 125,134       |
| 2005-2009   | 2550 | 65,780             | 119,510       |
| 2006 (Wet)  | 1470 | 37,920             | 68,894        |

The potential loading from continued seawater intrusion is estimated using existing locations of elevated chloride levels along the coast. This coastal area within the 2011 extent of seawater intrusion is characterized as high potential for salt loading from seawater intrusion (Figure 5.10). The average inland rate of seawater intrusion based on a 50-year record of the extent of coastal groundwater chloride concentrations in excess of 100 mg/L, which mostly pre-dates the Agency's supplemental water supply facilities, is approximately 180 feet/year. Based on an average inland rate of 180 ft/year of seawater intrusion projected out to a 30-year time horizon, areas within 1.0 mile of the current estimated boundary of seawater intrusion are categorized as having a moderate potential of salt loading due to seawater intrusion. Areas beyond 1.0 mile inland are categorized as low potential because they are likely beyond the expected zone of impact for seawater intrusion. Table 5.3 summarizes the acreage results shown in Figure 5.10.

**Table 5.3:** Acreage summary of seawater intrusion migration potential (Figure 5.10).

| Seawater intrusion migration potential | Area Distribution (acres; %) |
|----------------------------------------|------------------------------|
| HIGH                                   | 11,098; 15%                  |
| MODERATE                               | 5,568; 8%                    |
| LOW                                    | 55,461; 77%                  |

While PVWMA maintains a vast monitoring network, there are some spatial and vertical data gaps that make it more difficult to monitor seawater intrusion into Pajaro Valley. Many monitoring wells are located on privately owned land. When water quality in intruded wells degrades below levels suitable for agricultural irrigation or for household uses, the landowners or growers may discontinue using the

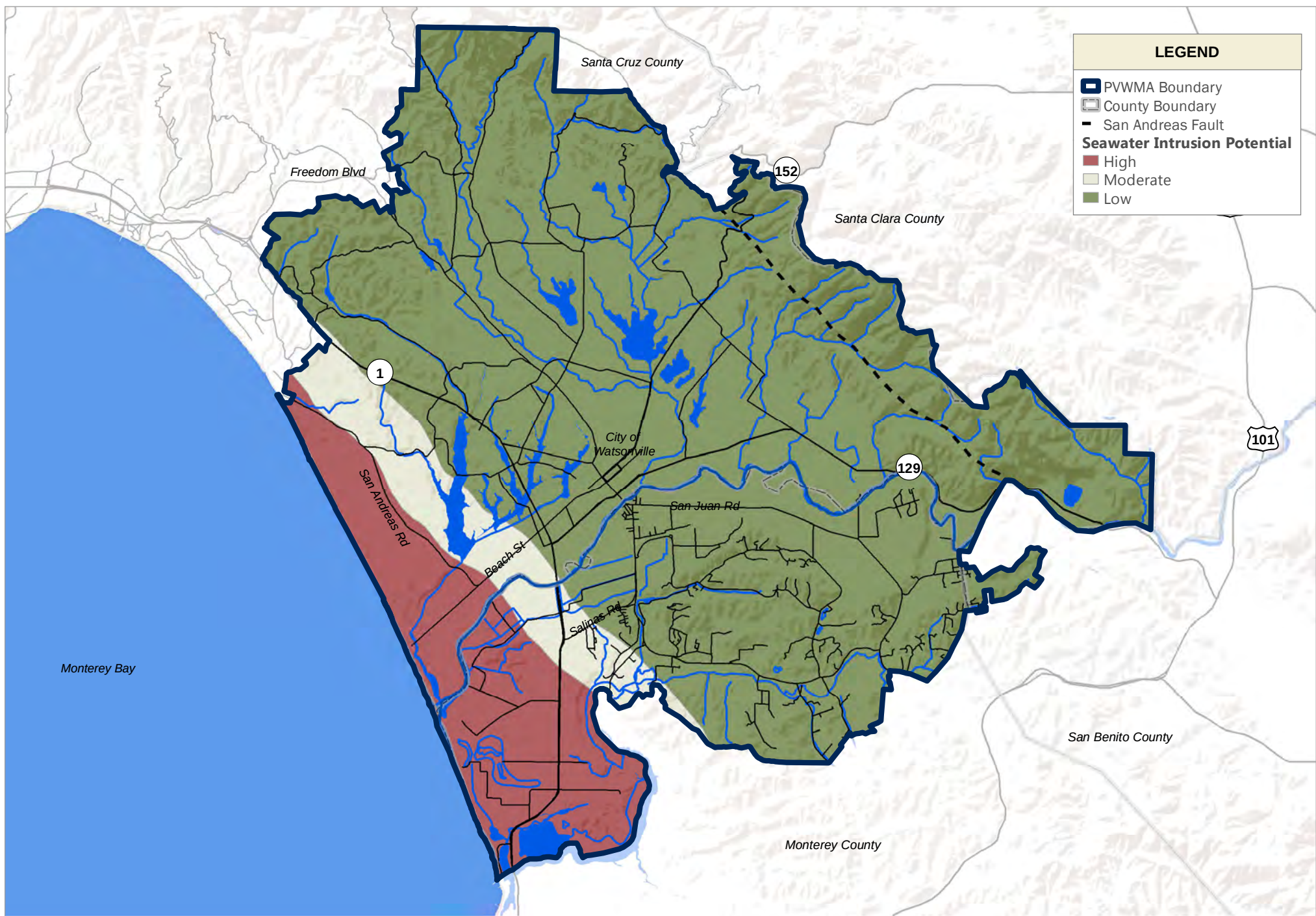


FIGURE 5.10: Potential of seawater intrusion based on distance from the 2011 inland extent (PVWMA, 2011) (Figure 4.6). The high potential polygon delineation is based on the best available data that does include sampling limitations.

well, and as a result, the well is often destroyed. In some cases, wells with decade's worth of data are among those destroyed. PVWMA is working to improve the well monitoring network by constructing dedicated monitoring wells used to supplement existing monitoring wells in order to better track changes to groundwater quality and quantity throughout the PVGB (Chapter 9.1).

As part of the BMP's goals to balance the water budget and stop seawater intrusion, the Agency commenced deliveries of supplemental water supplies through the CDS in 2002. By 2009, over 20 miles of CDS had been constructed, and the DWZ exceeded 7,600 acres. The sources of water provided to growers as supplemental irrigation supply is a blend of recycled water, water from the Harkins Slough Facility Recovery Wells, PVWMA Blend Wells, and City of Watsonville Potable Water Supply.

## 5.2.2 IRRIGATION WATER SALT LOADING POTENTIAL

Irrigation of crops can lead to salt build up in topsoil, especially during drier than average years when limited rainfall does not flush salts deeper into the soil column. Many high value crops grown in the Pajaro Valley are salt sensitive. A common response by growers to salt build up in topsoil is to apply irrigation water in order to leach salts to greater depths below the root zone, especially in the event of below average winter rainfall (Figure 4.1). The relative salt loading potential from irrigation water is derived from the TDS content of irrigation water (Figure 4.4) and groundwater recharge potential at the same location (Figure 5.8). By integrating recharge and concentration data, we can identify areas with high susceptibility to recharge that are also likely being irrigated with water containing elevated concentration of salts (Figure 5.11).

The water sources for irrigation of agricultural land area within the Pajaro Valley, in most cases, is either groundwater produced from privately owned production wells close to the ranch, delivered supplemental water, or a combination of the two. Therefore, it is reasonable to assume that the TDS content of irrigation water at a particular location is the existing average annual TDS concentration of the local groundwater (Figure 4.4), except within the area of the DWZ, where irrigation supply is a combination of delivered water and locally pumped groundwater. For simplicity, within the DWZ the average TDS concentration of 612 mg/L was used, which is based on hundreds of water samples collected by PVWMA at turnouts within the CDS from 2009-2015. A decision matrix was created to categorize the existing data and intersect the recharge potential map and the existing average TDS concentrations (Table 5.4). The datasets were combined in a manner that determines the relative loading potential as a categorical result. The results are displayed in Figure 5.11 and summarized in Table 5.5.

**Table 5.4:** Decision matrix to determine categorical irrigation salt loading potential within PVGB. Note that ranches within the DWZ were assigned a TDS concentration of 612 mg/L or relatively moderate TDS content.

| Groundwater TDS (mg/L)<br>(Figure 4.4) | GW Recharge Potential (Figure 5.7) |      |      |
|----------------------------------------|------------------------------------|------|------|
|                                        | Low                                | Mod  | High |
| High (>1000)                           | MOD                                | HIGH | HIGH |
| Mod (450-1000)                         | LOW                                | MOD  | HIGH |
| Low (<450)                             | LOW                                | LOW  | MOD  |

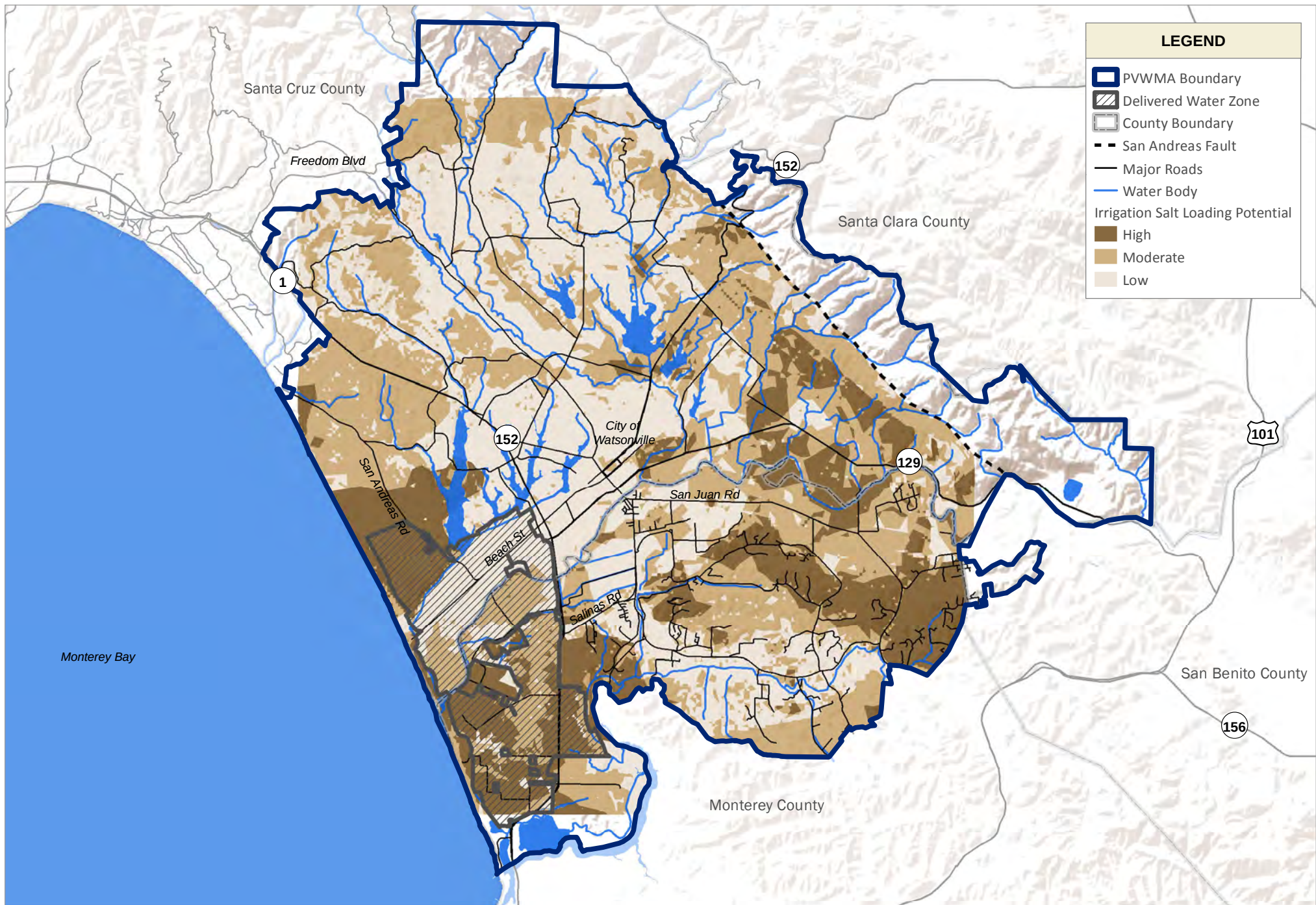


FIGURE 5.11: Categorical irrigation salt loading potential to groundwater within PVWMA as a result of the TDS content of the irrigation water and groundwater recharge potential (Figure 5.8). Lands within the Delivered Water Zone (DWZ) are assumed to utilize this source with an average TDS concentration of 612 mg/L. For lands outside of the DWZ it is assumed the land surface is irrigated using an adjacent groundwater well that possess the existing average TDS concentration of the groundwater (Figure 4.4).

**Table 5.5:** Acreage summary of categorical TDS loading potential (Figure 5.11).

| Irrigation TDS loading potential | Area Distribution (acres; %) |
|----------------------------------|------------------------------|
| HIGH                             | 13,180; 20%                  |
| MODERATE                         | 28,060; 42%                  |
| LOW                              | 26,100; 39%                  |

Areas with relatively high salt loading potential as a result of irrigation are predominantly located along the coast and along the northeastern boundary near Chittenden Gap, where TDS concentrations and relative recharge potential are both high.

### 5.2.3 STREAM SALT RECHARGE POTENTIAL

The potential for salt loading via in-stream recharge is based on streambed recharge rates and the salt content of the water being recharged. To estimate the stream salt recharge potential, the surface water TDS concentrations during baseflow conditions (Q3 in Figure 4.11) were intersected with the stream permeability distribution developed for the PVHM (Figure 5.9). The third quarter (June 1 through August 31) represents the dry season and typically worst surface water quality conditions. Late summer and early fall is also the time of year when shallow groundwater elevations are at seasonal lows. Table 5.6 is the categorical loading matrix used to identify the expected impact to local groundwater TDS content for each of the PVWMA sampling locations and the resultant stream infiltration salt loading is shown in Figure 5.12. The datasets were combined to determine the relative loading potential as a categorical result, not a quantitative estimate of annual loading. The designation between different TDS concentrations were based on the ranges defined in Chapter 4.2.1 and are based on irrigation standards.

**Table 5.6:** Decision matrix to determine stream infiltration salt loading potential within the PVGB to produce Figure 5.12

| Stream bed vertical conductivity | Q3 TDS MEAN concentration (Figure 4.11) |                        |                     |
|----------------------------------|-----------------------------------------|------------------------|---------------------|
|                                  | Low<br>< 450 mg/L                       | Mod<br>450 - 1000 mg/L | High<br>> 1000 mg/L |
| High (> 1.0- m/day)              | MOD                                     | HIGH                   | HIGH                |
| Mod (0.25-1.0 m/day)             | LOW                                     | MOD                    | HIGH                |
| Low (<0.25 m/day)                | LOW                                     | LOW                    | MOD                 |

The following procedure details how the surface water vertical conductivity data (Figure 5.9) was intersected with the surface water TDS concentrations to create results presented in Figure 5.12. The procedure begins with upstream reaches in the PVGB and progresses downstream.

1. For streams where TDS concentrations were available in the uppermost portion of the stream, the TDS mean concentration class was intersected with the vertical conductivity class following Table 5.6. If surface water concentration data was not available for the uppermost stream reach, then the relative potential recharge class was set equal to the stream bed vertical conductivity class.

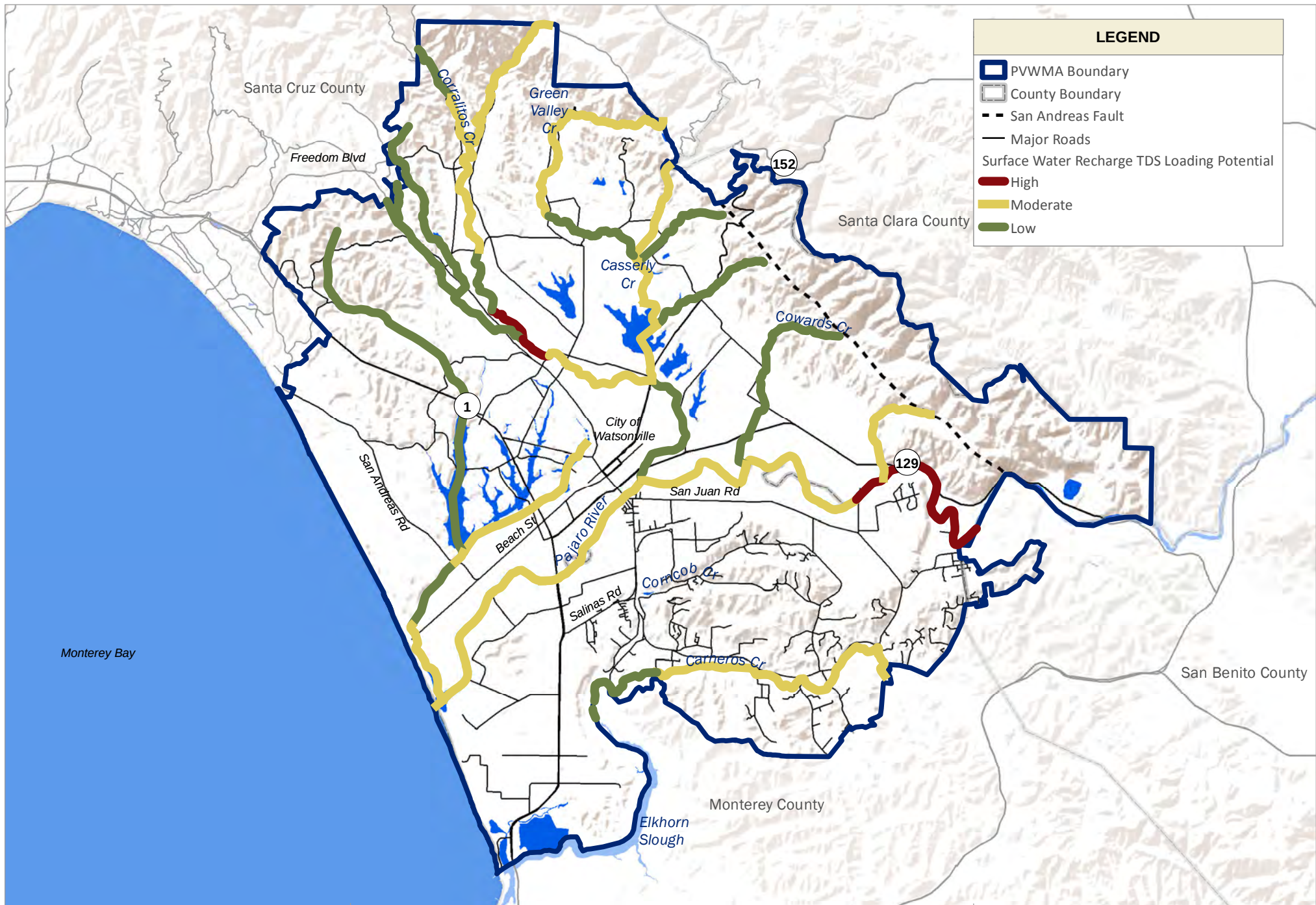


FIGURE 5.12: Categorical surface water recharge salt loading potential based on the integration of relative streambed vertical conductivity (Figure 5.9) and baseflow average TDS concentrations as measured at PVWMA surface water monitoring stations (Figure 4.11).

2. The relative potential recharge class was not changed until the mean concentration or the vertical conductivity class changed. When a change occurred, the decision matrix was applied again to define a new potential recharge class along the reach.
3. When two stream reaches joined together with different relative recharge classes, the higher potential loading class was assigned.

Sites with low surface water loading potential for salts are locations where either stream recharge is low or water quality data indicate the baseflow TDS concentration are low (below 450 mg/L). Figure 5.12 indicates that the locations with the greatest salt loading potential to groundwater via stream recharge are the Pajaro River between Chittenden Gap and Murphy Crossing and along a central reach of Corralitos Creek. Tracers such as boron and chloride, which can also be used to indicate high stream recharge, also have elevated reported concentrations along the uppermost portion of the Pajaro River (Russo *et al.* 2013). The often poor late summer or fall Pajaro River water quality at the eastern PVGB boundary and the high vertical conductivity of this upper reach has been attributed as the cause of the elevated TDS in groundwater in the eastern region (Hecht *et al.* 2010 and Figure 4.4). Reaches of moderate stream salt loading are located in the northeastern areas on Corralitos Creek and other tributaries.

The average annual salt loading to groundwater from streams can be approximated using the PVHM groundwater budget stream infiltration estimates and average concentrations of TDS and chloride. The PVHM groundwater budget summary (Table 3.1) estimates a stream infiltration rate of 14,960 AFY. Average chloride and TDS concentrations were spatially weighted by taking the average concentration (Figures 4.11, 4.12) at each monitoring location and associated stream reach length. The basin-wide average concentration in streams is 222 mg/L for chloride and 836 mg/L for TDS. These values are multiplied by the average annual infiltration rate of 14,960 AFY, resulting in loads of 4,520 t chloride/year and 17,010 t TDS/year. Surface water conditions are highly variable depending on a number of factors including time of year and total volume of streamflow. Table 5.7 represents an estimate of salt loading from streams to groundwater based on available data sources.

**Table 5.7:** Estimated TDS and chloride loading to groundwater from streams based on an average annual infiltration rate of 14,960 AFY.

| Relative loading to groundwater from stream infiltration | Estimated mean concentration in streams in PVGB (mg/L) | Estimated load to groundwater from streams (t/yr) |
|----------------------------------------------------------|--------------------------------------------------------|---------------------------------------------------|
| <b>TDS</b>                                               | 836                                                    | 17,010                                            |
| <b>Chloride</b>                                          | 222                                                    | 4,520                                             |

#### 5.2.4 PVGB SALT LOADING POTENTIAL

Total salt loading to groundwater in the PVGB is sensitive to TDS concentrations in irrigation water, groundwater recharge, and seawater intrusion. The combined salt loading to the Basin is determined by intersecting the seawater intrusion potential (Figure 5.10) with irrigation salt (TDS) loading (Figure 5.11). The decision matrix for determining the integrated salt loading potential to groundwater is shown below in Table 5.8, and is used to generate the map in Figure 5.13. Land within the high seawater intrusion potential zone is defined as high salt loading potential because chloride and TDS concentrations in seawater are exceedingly high and pose a risk to groundwater further inland. Figure 5.13 also overlays the results of stream loading potential analysis (Figure 5.12) to reflect the distinct

loading pathway to groundwater in riparian areas. Table 5.9 summarizes the acreage of results displayed in Figure 5.13.

**Table 5.8:** Decision matrix to determine combined (irrigation water and seawater) salt loading potential in the PVGB.

| SW Intrusion Potential | Irrigation TDS Loading Potential (Figure 5.12) |      |      |
|------------------------|------------------------------------------------|------|------|
|                        | Low                                            | Mod  | High |
| High                   | HIGH                                           | HIGH | HIGH |
| Mod                    | MOD                                            | MOD  | HIGH |
| Low                    | LOW                                            | LOW  | MOD  |

**Table 5.9:** Acreage summary of combined salt (TDS and chloride) loading potential (Figure 5.13).

| Integrated salt loading potential | Area Distribution (acres; %) |
|-----------------------------------|------------------------------|
| HIGH                              | 11,130; 17%                  |
| MODERATE                          | 11,560; 17%                  |
| LOW                               | 44,650; 66%                  |

Figure 5.13 shows that the highest priority areas are along the coast where the seawater intrusion potential is high. Moderate loading potential is in the upper Pajaro River where surface water salt concentrations and recharge potential is elevated. The rate of seawater intrusion is influenced by a combination of the degree of groundwater pumping and the amount of recharge within the basin. Increased pumping of groundwater in a significantly over drafted basin with groundwater elevations below sea level will cause seawater to migrate inland. PVHM simulations have shown water management practices that decrease the volume of groundwater production can lower the rate of seawater intrusion (Hanson *et al.*, 2014). The assimilative capacity of salts in the Basin is discussed in Chapter 7 of this report.

## 5.3 Nitrate Loading Potential

The primary sources of nitrate loading to groundwater included in this analysis include: streamflow recharge (Chapter 5.3.1), agricultural land use practices (Chapter 5.3.2), sewer system (Chapter 5.3.3), and septic systems (Chapter 5.3.4). Nitrogen cycles through the atmosphere and biosphere in various forms including dinitrogen gas ( $N_2$ ), nitrous oxide ( $N_2O$ ), nitrogen oxides ( $NO_x$ ), nitrite ( $NO_2$ ), nitrate ( $NO_3$ ), and organic nitrogen (Norg). The streamflow recharge section discusses the dissolved concentration of nitrate- $NO_3$  consistent with datasets displayed in Chapter 4.2. The agricultural loading analysis refers to the potential amount of nitrogen delivered to the groundwater from multiple sources (e.g., fertilizer application, irrigation). The quantitative approach discussed in Chapter 5.3.2 closely follows the detailed nitrogen loading analysis completed for the Salinas Valley by Viers *et al.* (2012). Existing land use, recharge potential and source distribution mapping is used to identify and compare the theoretical rates of nitrate loading across sources within the PVWMA area.

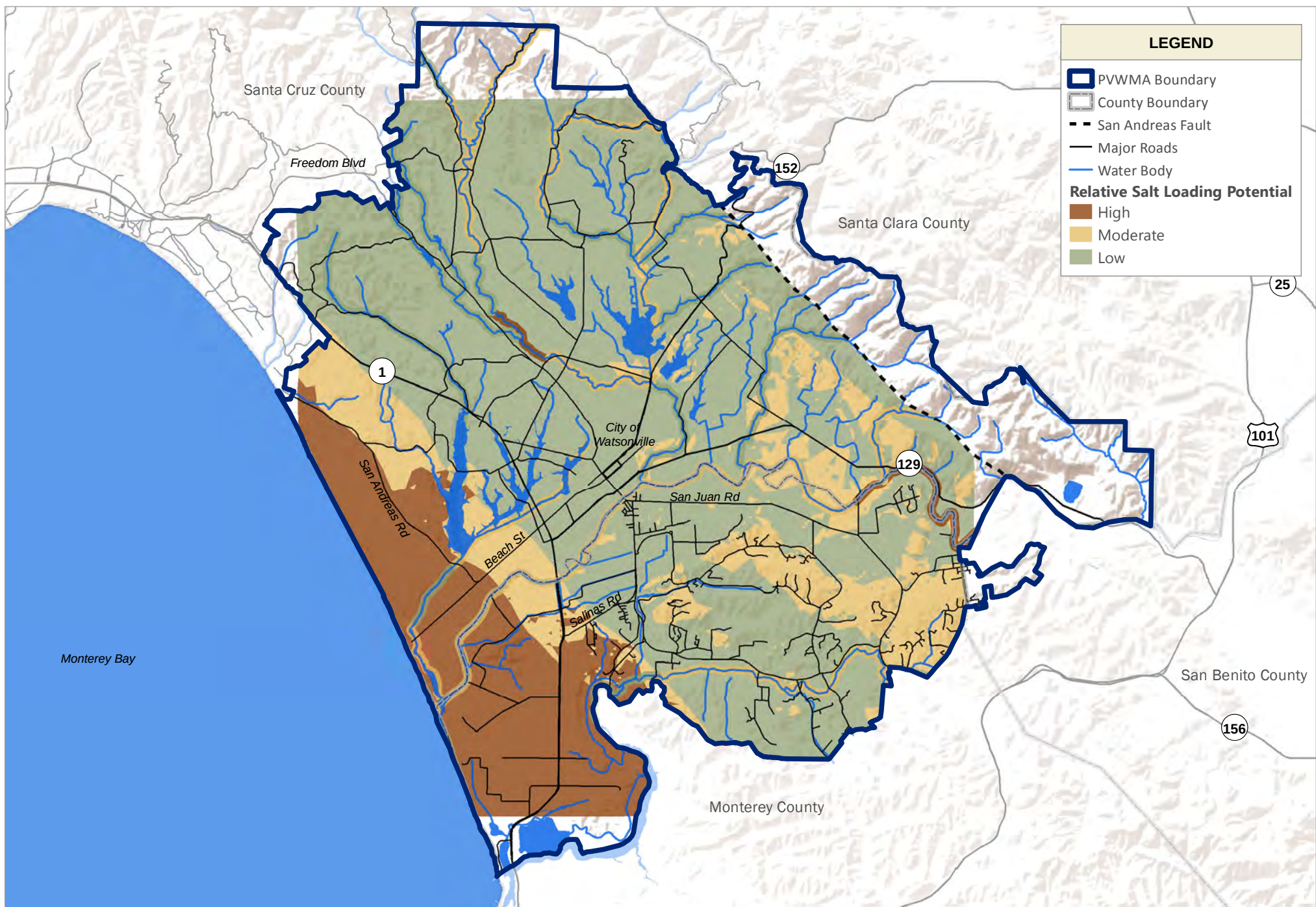


FIGURE 5.13: Categorical potential of salt loading to groundwater created with the intersection of Irrigation Salt Loading Potential (Figure 5.10) with the Seawater Intrusion Potential (Figure 5.11) along with surface water recharge potential (Figure 5.8) using the process detailed in section 5.2.4.

### 5.3.1 STREAM NITRATE RECHARGE POTENTIAL

The potential of nitrate-NO<sub>3</sub> loading to groundwater via surface water recharge is assumed to be based on the streambed recharge rates and the nitrate-NO<sub>3</sub> content of the water being recharged. To create these comparisons, surface water nitrate-NO<sub>3</sub> concentrations during baseflow conditions (Q3 in Figure 4.13) were intersected with the PVHM stream permeability distribution (Figure 5.9), similar to the approach for salt loading potential for streams (Chapter 5.2.3). Table 5.10 is the loading matrix used to identify the expected impact to local groundwater nitrate-NO<sub>3</sub> content for each of the PVWMA sampling locations and the resultant stream infiltration nitrate-NO<sub>3</sub> loading is shown in Figure 5.14. The process to combine datasets to create Figure 5.14 is a categorical approach, and does not represent a quantitative estimate of nitrate loading to the PVGB.

**Table 5.10:** Decision matrix to determine stream infiltration nitrate loading potential to produce Figure 5.14

| Stream bed vertical conductivity | Q3 nitrate-NO <sub>3</sub> MEAN concentration (Figure 4.13) |                   |                  |
|----------------------------------|-------------------------------------------------------------|-------------------|------------------|
|                                  | Low<br><10 mg/L                                             | Mod<br>11-45 mg/L | High<br>>45 mg/L |
| High (> 1.0- m/day)              | MOD                                                         | HIGH              | HIGH             |
| Mod (0.25-1.0 m/day)             | LOW                                                         | MOD               | HIGH             |
| Low(<0.25 m/day)                 | LOW                                                         | LOW               | MOD              |

As shown in Figure 5.14, low potential loading sites are locations, such as Carneros Creek and other smaller streams, where either stream recharge is low or streams have low nitrate-NO<sub>3</sub> content. Similar to the results shown in Figure 5.12 for stream salt recharge, the areas of high stream nitrate recharge are associated with the inherited poor water quality from the upper Pajaro River watershed that is transported to a reach with very high stream bed vertical conductivity.

In order to generate loading estimates from streams that can be generally compared to the estimates from other sources, the estimated amount of nitrate-N (nitrate as nitrogen) loading to groundwater from streams was calculated. To do this we utilized the average annual streamflow infiltration volume and the high, moderate, and low estimates of nitrate concentration in surface water. The 2015 estimate of streamflow infiltration is 14,960 AFY based on the PVHM groundwater budget. The average basin wide concentration of nitrate-NO<sub>3</sub> in streams is 20 mg/L and is estimated by taking the weighted sum of nitrate-NO<sub>3</sub> concentration at each monitoring location (Figure 4.8) and the associated stream reach length. In order to maintain consistency in comparisons between other sources of nitrogen (i.e., sewer, agriculture) low and high estimates for the nitrate concentrations in surface waters is determined by taking 20% below and above the average, yielding 16 mg/L and 24 mg/L respectively. When multiplied by the annual infiltration rate of 14,960 AFY, the theoretical nitrate-N loads range from 73 to 110 t N/yr leached to groundwater as a result of stream infiltration. Actual N loading to groundwater from streamflow infiltration will vary by season and by year as surface water concentrations can go up and down depending on the time of the year and total volume of streamflow. The estimates provided in Table 5.11 provide a range of nitrate-N loading to groundwater based on best available data.

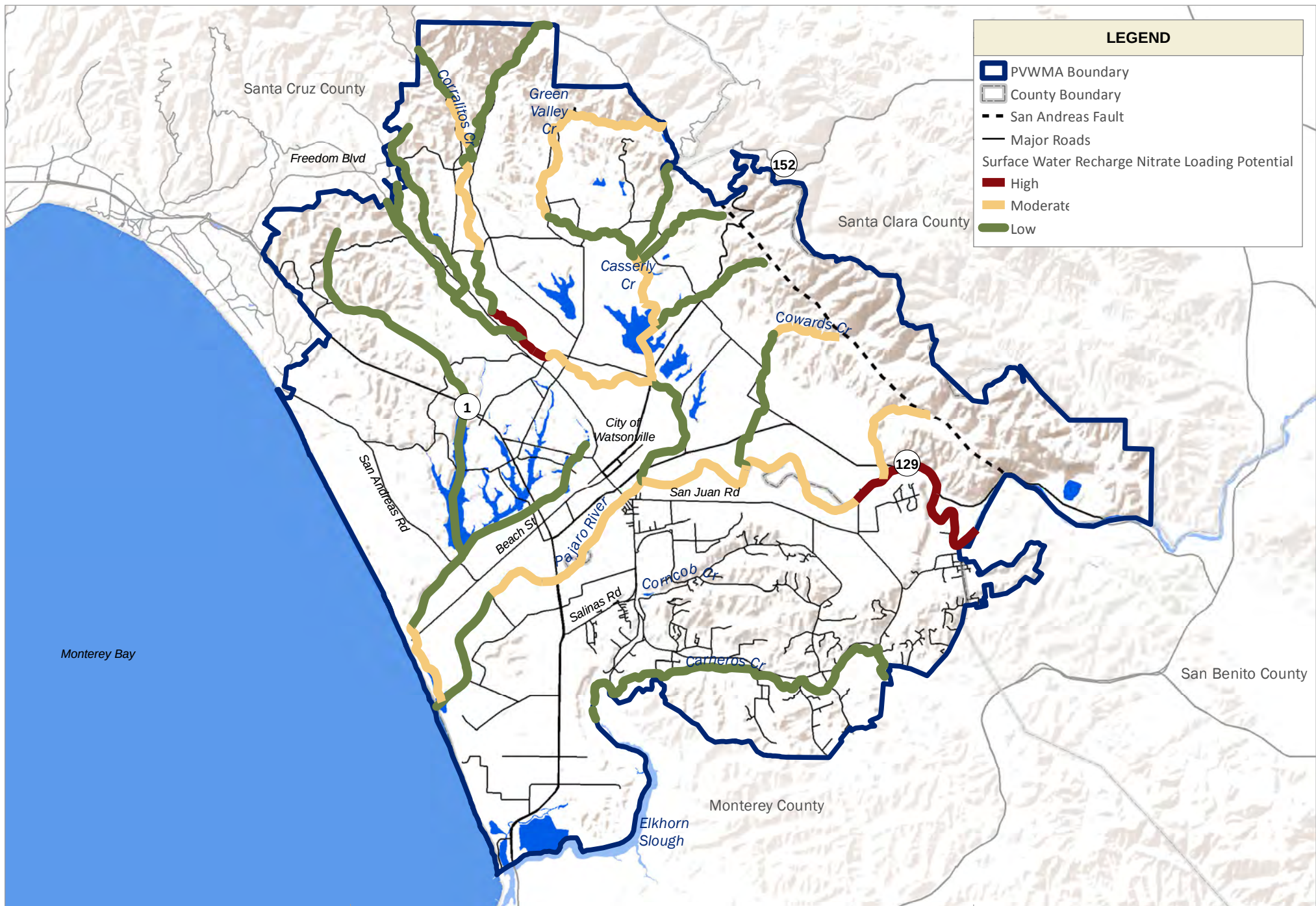


FIGURE 5.14: Categorical surface water recharge nitrate loading potential based on the integration of relative streambed vertical conductivity (Figure 5.9) and baseflow average nitrate concentrations as measured at PVWMA surface water monitoring stations (Figure 4.13)

**Table 5.11:** Estimated nitrate-N loading to groundwater from streams based on an average annual infiltration rate of 14,960 AFY.

| N loading to groundwater from stream infiltration | Estimated mean NO <sub>3</sub> concentration in streams in PVGB (mg/L) | Estimated nitrate-N load to groundwater from streams (t N/yr) |
|---------------------------------------------------|------------------------------------------------------------------------|---------------------------------------------------------------|
| <b>LOW</b>                                        | 16                                                                     | 73                                                            |
| <b>AVG</b>                                        | 20                                                                     | 91                                                            |
| <b>HIGH</b>                                       | 24                                                                     | 110                                                           |

### 5.3.2 AGRICULTURAL NITROGEN LOADING POTENTIAL

Agricultural land use is known to be a significant source of nutrients to groundwater basins from irrigation and fertilizer application practices throughout the U.S, and the Pajaro Valley is one of the most productive agricultural regions in the country. As previously mentioned, the nitrogen cycle is very complex involving multiple sources and reservoirs of N, as well as many processes affecting changes and environmental fates of different N compounds (Figure 4.2). The largest reservoir of N in the soil is the organic N reservoir consisting of plant residues, soil organic matter and microbial biomass. In actively cultivated soils, it is estimated that there is over 13,000 pounds of organic N per acre-foot of soil (Tisdale *et al.*, 1993). In the Pajaro Valley, the crop rooting depth and plant residue incorporation methods extend this reservoir to two feet below the soil surface. Thus, the organic N reservoir in the Pajaro Valley is estimated to contain over 26,000 pounds of N per acre.

Forms of inorganic N applied in agriculture are actively and passively absorbed by plant roots and microbes in the organic N reservoir. The nitrogen in the organic N reservoir is unavailable for leaching until it is converted to nitrate-N. To create a comprehensive model of nitrogen loading and subsequent nitrate leaching, the amount of N entering the organic N reservoir and the amount of organic N being converted to nitrate must be calculated. At the current time, this is an extremely difficult task due to the influence of many variables including crop uptake rates, soil moisture, temperature, organic matter levels, and levels of microbial activity. Therefore, nitrogen loading and nitrate leaching models have typically excluded this nitrogen reservoir and its significant effect on the environmental fate of the nitrogen applied in agricultural systems.

This SNMP analysis uses one of the more multifaceted models in the literature, published in 2012 (Viers *et al.*). The model includes three nitrogen input variables and three nitrogen output variables and is described in detail below. The Viers *et al.* (2014) methodology aligns with the best available data inputs for the Pajaro Valley and was determined to be the most appropriate model to meet the development objectives of the SNMP. However, there are some known limitations to the model. As described above for typical nitrogen loading models, the methodology excludes any calculation of the amount of nitrogen entering the organic N reservoir as plant residues or any rates of conversion of organic N to nitrate. Viers *et al.* (2014) also fails to incorporate all of the daily, seasonal and annual variability in climate, precipitation, crop types, land management practices and other factors that influence the complexity of pollutant fate and transport. While the analysis is the most complex published for California, it does not truly quantify the amount of nitrate-N potentially leaching to groundwater for any specific time scale.

The modeled rate of loading of nitrate to groundwater from agricultural lands in the PVGB is estimated by leveraging the approach of Viers *et al.* (2012) who conducted an extensive nitrate groundwater loading analysis for the Tulare Lake Basin and the Salinas Valley. Viers and co-authors completed a

mass balance analysis of the nitrogen inputs and losses on agricultural lands to estimate an annual load of nitrate leaching to groundwater. Closely following Viers *et al.* (2012), a quantitative nitrogen loading analysis was conducted for the PVGB. Available recent agricultural land use mapping (2011/2012) and knowledge of land management practices within the PVGB were incorporated. Using a similar approach to Viers *et al.* (2012) and available data for the PVGB, we provide a high, moderate, and low estimate of modeled annual nitrate loading to groundwater from agricultural lands in this section.

### 5.3.2.1 AGRICULTURAL LAND USE

Accurate delineation of agricultural land use and crop type is an important component in the Viers *et al.* (2012) approach to nitrate loading. Care was taken to obtain the most accurate and relevant information known to be available for the Pajaro Valley and the analysis herein incorporates land use and crop type data from collected in 2011 and 2012 by PVWMA staff. It is understood that the 2011/2012 PVGB agricultural land use distribution is a snapshot in time and that the crop distribution and management practices do change.

The agricultural land use distribution within the basin is shown in Figure 5.15, and Figure 5.16 provides additional detail of the crop type in 2012. Given the regular rotation of crops, the 2012 PVWMA crop mapping could potentially misrepresent the land use designation as fallow for some parcels. Therefore, 2011 was used as supplemental layer to verify if a parcel was fallow two sequential years prior to fallow designation. If a parcel was fallow in 2012 but mapped by the PVWMA as an active crop in 2011, the parcel was assigned the crop type present in 2011.

Figure 5.16 and Table 5.12 present the crop type category designations and resulting total acreage under each land use that collectively comprise the 28,230 acres (including fallow) of cultivated land within the basin or 39% of the land west of the San Andreas Fault. Note that the total mapping area conducted by the PVWMA within the PVGB is 72,130 acres.

**Table 5.12:** 2011/2012 crop use acreage summary of Figure 5.16 and the percentage of agricultural land within the PVGB.

| Land Use Category                                                    | Acres         | % of total PVGB |
|----------------------------------------------------------------------|---------------|-----------------|
| Vegetable Row Crops, Artichokes                                      | 9,140         | 12%             |
| Strawberries                                                         | 7,990         | 11%             |
| Horticultural Nurseries                                              | 1,340         | 2%              |
| Cane berries                                                         | 5,000         | 7%              |
| Deciduous (Apple Orchards)                                           | 2,180         | 3%              |
| Other, Unknown Agriculture,<br>Vine/Grapes                           | 1,140         | 2%              |
| Fallow Land                                                          | 1,440         | 2%              |
| <b>Total Agricultural Land Use,<br/>including fallow (2011/2012)</b> | <b>28,230</b> | <b>39%</b>      |
| Non-Agricultural land uses                                           | 43,900        | 61%             |
| <b>Total PVGB area</b>                                               | <b>72,130</b> | <b>100%</b>     |

Existing agricultural land use distribution and general management practices based on Table 5.12 are used to estimate nitrogen loading specific to the PVGB.

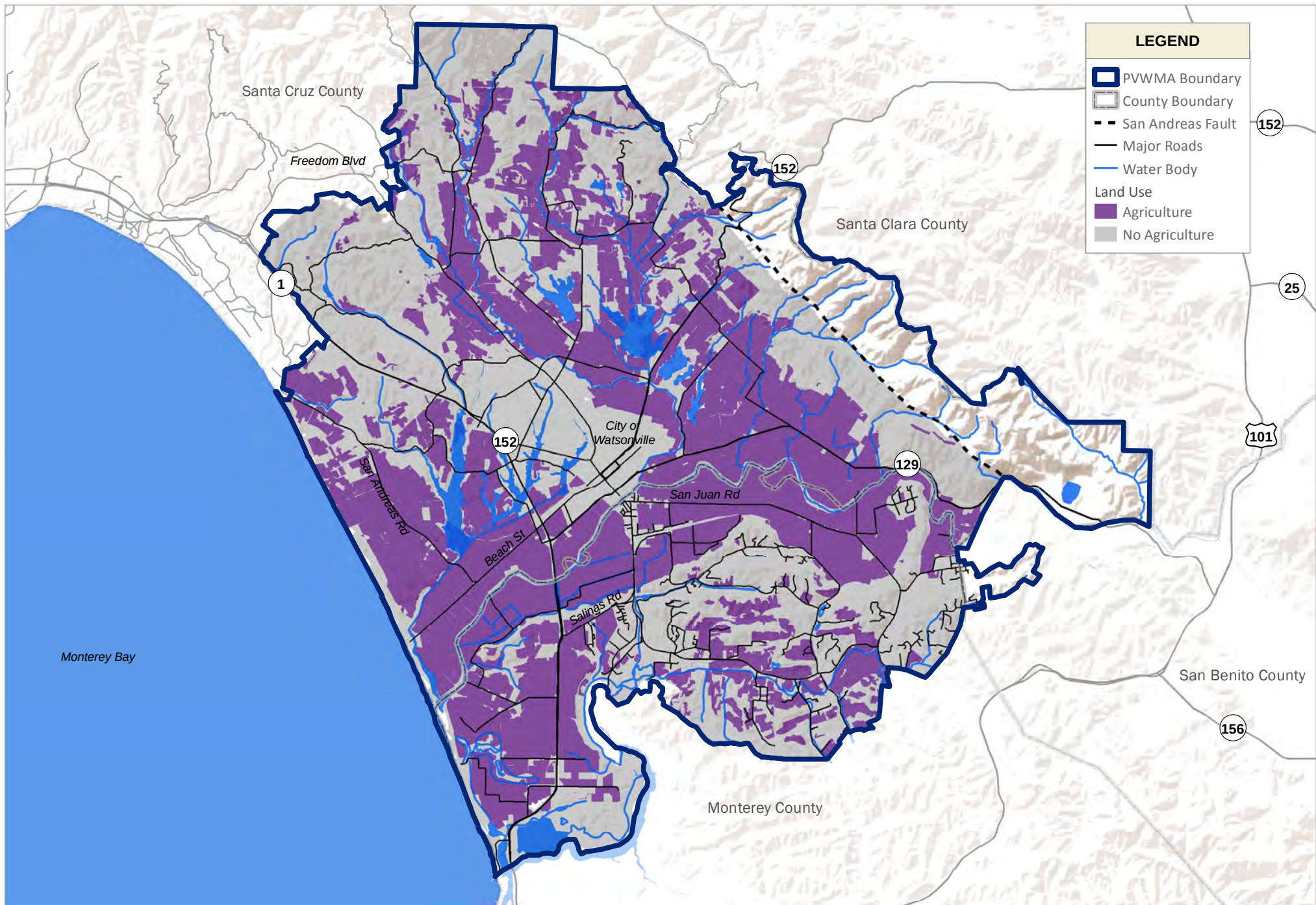


**FIGURE 5.15: Agricultural land use (2010-2012) within the PVWMA boundary. Land use designations were provided by the PVWMA.**

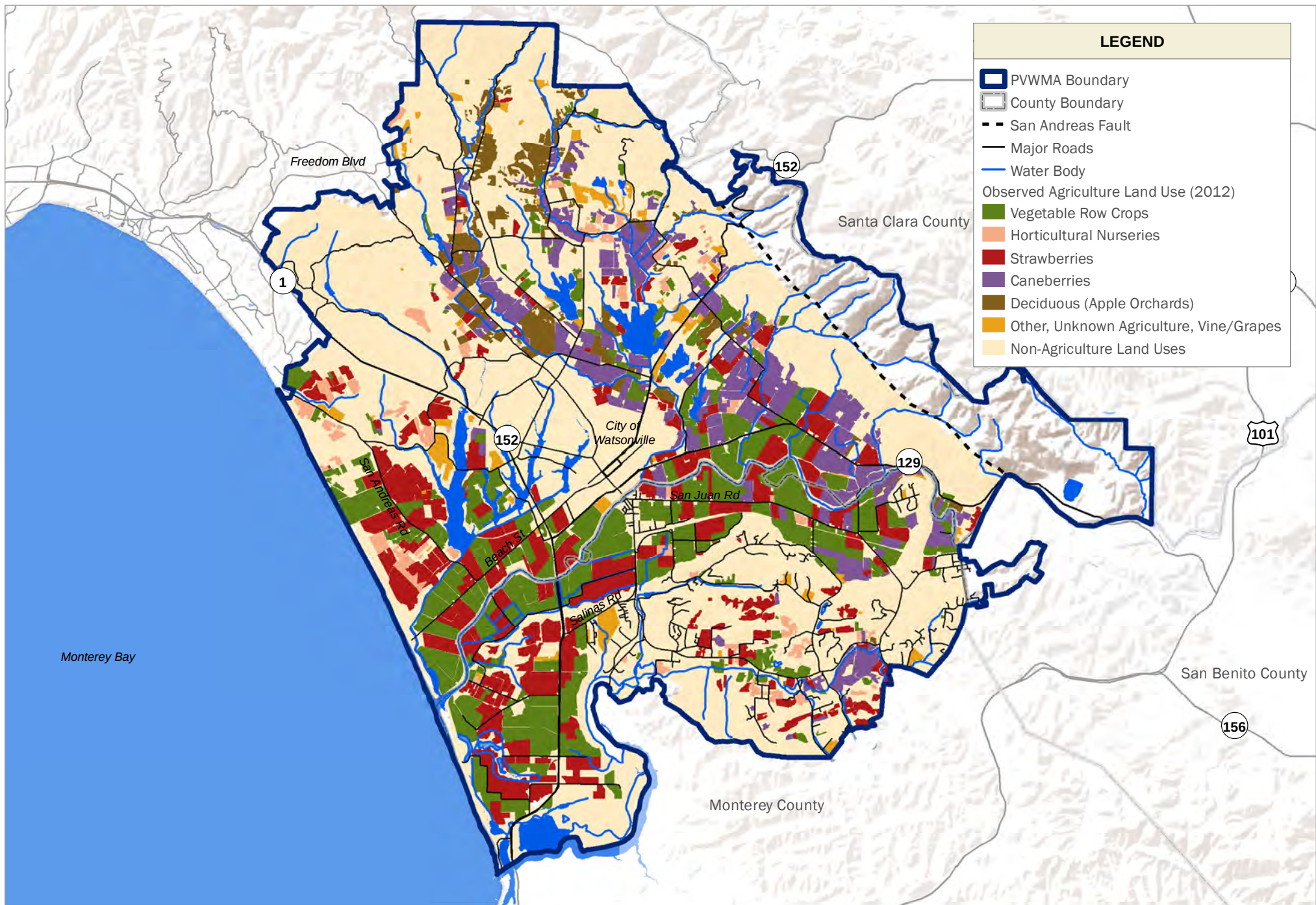


FIGURE 5.16: Agriculture crop distribution based on assigned crop type designations from land use data provided by PVWMA.

### 5.3.2.2 NITROGEN INPUTS AND OUTPUTS

Viers *et al.* (2012) quantified nitrogen inputs and outputs to estimate the average annual flux to shallow groundwater as a result of agricultural practices. In its most simple form, the average annual flux (lbs/acre/yr) of nitrogen remaining in the system and potentially available for leaching to groundwater,  $N_{GW}$ , in the form of total nitrogen (N), was estimated based on the following equation:

$$N_{GW, AVG} = N_{inputs, avg} - N_{outputs, avg} \quad (\text{Eqn. 1})$$

Where the inputs include fertilizer application, irrigation inputs, and atmospheric deposition and the outputs include harvested nitrogen, surface runoff, and evaporative losses to the atmosphere. For each of the three input and output variables we estimate high, moderate, and low nitrogen loads (inputs) and nitrogen losses (outputs). To obtain a minimum endmember estimate for the theoretical amount of nitrogen remaining in the system and available for leaching to groundwater, we paired the low nitrogen input estimates with the high nitrogen output estimates:

$$N_{GW, MIN} = N_{inputs, min} - N_{outputs, max} \quad (\text{Eqn. 2})$$

To obtain a maximum endmember estimate for the theoretical amount of nitrogen remaining in the system and available for leaching to groundwater, we paired the high nitrogen inputs with the low nitrogen outputs:

$$N_{GW, MAX} = N_{inputs, max} - N_{outputs, min} \quad (\text{Eqn. 3})$$

We note that specific agricultural practices vary from year to year based on climate variability, the productivity of the previous year, and incorporation of new technologies. The data presented herein represent a snapshot for a range of theoretical nitrogen and nitrate leaching estimates to groundwater using the best available data. Table 5.13 provides key unit conversions when estimating nitrogen loads from land use practices. The conversion from nitrate- $\text{NO}_3$  concentrations in groundwater to nitrate-N concentrations in irrigation water and nitrogen loads on agricultural fields is critical.

**Table 5.13:** Constant values to estimate nitrogen inputs from land use practices.

| acre-feet (ac-ft) | liters (L) | nitrate-N<br>(mg/L) | nitrate- $\text{NO}_3$<br>(mg/L) | short ton<br>(t) | pounds<br>(lbs) | nitrate- $\text{NO}_3$<br>(mg/L) | nitrate-N<br>(lbs/ac-ft) |
|-------------------|------------|---------------------|----------------------------------|------------------|-----------------|----------------------------------|--------------------------|
| 1                 | 1,233,482  | 1                   | 4.43                             | 1                | 2000            | 1                                | 0.368                    |

As identified in Viers *et al.* (2012), the primary inputs or sources of nitrogen pertinent to agricultural land use and the manner in which they are applied in the Pajaro Valley include the following:

- **Fertilizer application** – A significant input of nitrogen to the PVGB, fertilizer is applied to fields to promote crop growth and increase yields. Estimated application rates by crop type are based on surveys conducted by PVWMA from 2009-2011 (Platts, 2011).
- **Irrigation inputs** – Another source of nitrogen inputs to the Pajaro Valley is from irrigation water. The nitrate-N concentration of water applied is an important input as well as the amount of water used to irrigate the fields, which varies by crop type. The nitrate- $\text{NO}_3$  concentration of water is estimated using the range of average groundwater concentrations presented in Figure 4.8. The ranges in water use by crop type are based on PVWMA and Monterey County Water Resources Agency (MCWRA) data for 2010-2013, and supplemented by results from published literature.

- **Atmospheric deposition** – Nitrous oxide from automobile or industrial exhaust is the primary source of nitrogen from the atmosphere. Ammonia volatilized from manure at concentrated animal feeding lots can also travel distances ranging from meters to thousands of kilometers once entrained in the atmosphere. These compounds can be fixed over agricultural lands and mobilized to groundwater via infiltration of irrigation waters or rain waters. Atmospheric nitrogen deposition estimates are extrapolated from modeled atmospheric patterns and measured data from California.

The relative groundwater recharge potential is important to note when evaluating the likelihood that these inputs will be delivered to the groundwater. The agricultural land use layer (Figure 5.15) was intersected with groundwater recharge potential layer (Figure 5.8) and yielded the following distribution of agricultural lands in each recharge potential area: 30.2% high (9,750 acres), 45.7% moderate (14,800 acres), and 24.1% low (7,800 acres). For the purposes of this analysis, an assumption that all agricultural lands were on moderate recharge potential areas was made to calculate an average  $N_{GW}$ . While a spatially discrete analysis, including crop distribution and groundwater concentration data along with groundwater recharge potential, could be performed to create a more refined analysis of the nitrate loading to the groundwater, the basin average was deemed appropriate to compare to the other potential sources (streamflow recharge, sewer and septic systems).

As identified in Viers *et al.* (2012), the primary outputs or losses of nitrogen and the manner in which they are applied in the Pajaro Valley include the following:

- **Harvested** – Plant uptake of nitrogen and removal of organic nitrogen from the system is referred to as the harvested quantity. This value was estimated with reported annual yields (tons/acre) by crop type via the US Department of Agriculture's (USDA) Crop Nutrient Tool (available online at [www.plants.usda.gov/npk/NutrientReport](http://www.plants.usda.gov/npk/NutrientReport)). The 2012 agricultural yields for the Pajaro Valley were estimated from the Santa Cruz and Monterey Counties ACRs (Santa Cruz County, 2012 Ag Report; Monterey County, 2012 Ag Report).
- **Surface runoff** – Agricultural practices tend to result in surface runoff resulting in nitrogen losses to streams. Surface runoff losses are estimated using results from nutrient loading models in the literature.
- **Atmospheric losses** – The annual loss rate of nitrogen gasses (dinitrogen gas, nitrous oxide, nitrogen oxides, and ammonia) emitted to the atmosphere over agricultural lands are the result of ammonium volatilization and denitrification in the root zone and at the land surface. Atmospheric losses are estimated from measured data collected in the Pajaro Valley.

Not included in the primary outputs are the use of tile drains to intercept irrigation volumes prior to their discharge to groundwater. Properly installed and maintained tile drain systems will capture and discharge water from below the root zone to drainage ditches that flow to surface water streams and off property. Based on best available spatial information, approximately 20% of the agricultural lands in the Pajaro Valley are underlain by tile drain systems. However, no information is available on design and/or maintenance of these systems. Given the uncertainty on the effectiveness of systems, including whether the systems do discharge volumes off-property, as well as the fact that their presence was not included by Viers *et al.* (2012), tile drains are not incorporated as a primary output of nitrogen in this analysis. With additional research on tile drain effectiveness within the Pajaro Valley, this could be included in a future analysis.

- **Potential leaching to groundwater** – Following the Viers *et al.* (2012) mass balance approach, the theoretical amount of nitrogen leaching to groundwater, in the form of total nitrogen (lbs/ac/yr) and ultimately nitrate-NO<sub>3</sub> (mg/L), can be estimated by the difference between all of the inputs and losses on an average annual basis. With the inputs and outputs described above, Equation 1 can be written more explicitly as:

$$N_{GW} = N_{fertil} + N_{irrig} + N_{deposit} - (N_{harvest} + N_{runoff} + N_{atmos\ loss}) \quad (\text{Eqn. 4})$$

To determine the minimum endmember nitrogen leaching to groundwater we use Equation 2. To determine the maximum endmember nitrogen leaching to groundwater we use Equation 3. Also provided is a moderate estimate of nitrogen leaching to groundwater based on Equation 1.

### 5.3.2.3 FERTILIZER APPLICATION

An estimate of the fertilizer application based on the 2011/2012 land use was used to determine fertilizer inputs specific to the PVGB. The annual mass of nitrogen applied to a crop is dependent on a number of factors including residual soil organic nitrogen content, winter rainfall, climate, and soil type. Multiple sources of data were used to develop reasonable range of annual nitrogen loading rates which capture the expected seasonal and site variability expected in the Pajaro Valley. Primary sources used to identify the nitrogen loading categories were:

1. PVWMA nitrate survey data from growers collected 2009 – 2011 (Platts, 2011),
2. A compilation of references detailing nitrogen use for different crops in California, Oregon and Idaho (Righetti *et al.* 1998, Mahler and Barney 2000, Pettygrove 2003, Hart *et al.* 2006a and 2006b, Smith *et al.* 2008, LeStrange *et al.* 2010, Turini *et al.* 2010), and
3. USDA NASS (2011a and 2011b) data for crops grown in California, Washington and Oregon. Including Washington and Oregon was necessary in order to get an adequate amount of data relevant to the diversity of cane berry crops grown in Pajaro Valley.

The categories are based on the actual annual rates of nitrogen applied to high production cost crops grown in the Pajaro Valley. This classification of crops is based on a general assessment of the practices over the last few years (2010-2013) and average reported amounts for the various crop types. Since fallow land does not receive fertilizer or irrigation, the 1,440 acres of fallow land was excluded from this table and the nitrogen loading analysis as a whole. However, depending on the business strategy of the individual agricultural producer and certain factors of crop production, there may be individual operations that have significantly different practices. The range of values used to estimate nitrogen inputs are based on differences in the relative fertilizer application rates estimated over the last few years. Estimated fertilizer application rates are provided in Table 5.14.

**Table 5.14:** Annual relative nitrogen inputs from fertilizer application using the 2012 crop distribution (Table 5.11)

| Annual fertilizer application relative intensity | Crop type                          | Estimate range of fertilizer application (N lbs/ac/yr) | Average fertilizer application (N lbs/ac/yr) | Agricultural area distribution (acres) | Area % of agricultural land |
|--------------------------------------------------|------------------------------------|--------------------------------------------------------|----------------------------------------------|----------------------------------------|-----------------------------|
| <b>Very High</b> <sup>a</sup>                    | row crops, strawberries            | > 250 <sup>a</sup>                                     | 250                                          | 7,770 <sup>a</sup>                     | 29% <sup>a</sup>            |
| <b>High</b>                                      | row crops, strawberries, nurseries | 150 to 250                                             | 200                                          | 10,700                                 | 40%                         |
| <b>Moderate</b>                                  | cane berries, tree fruit           | 76 to 149                                              | 112.5                                        | 7,180                                  | 27%                         |
| <b>Low</b>                                       | grapes, nurseries                  | 35 to 75                                               | 55                                           | 1,140                                  | 4%                          |
| Total agricultural land use                      |                                    |                                                        |                                              | 26,790                                 | 100%                        |

<sup>a</sup>Belinda Platts, on behalf of PVWMA, used the 2009 to 2012 agricultural land use to estimated 29%, or approximately 7,770 acres, of agricultural land in the PVWMA area is subject to annual fertilizer applications of >250 lbs N/acre/year. Very high usage crops are vegetable row crops and strawberries but exactly which areas within the Pajaro Valley are currently implementing these very high fertilizer application practices is uncertain. Thus, half of the 7,772 acres were allocated to the vegetable crops and half to the strawberries.

The data in Table 5.14 was used to calculate high, moderate and low estimates of nitrogen inputs using the estimated average crop acres. The methodology to estimate the potential highest level of nitrogen inputs used the high value of the range of fertilizer application for each crop grouping. For example, vegetable and strawberry crop acres were calculated using 250 lbs N/ac/yr and the other two crop groupings used 149 and 75 lbs N/ac/year. In contrast, the lowest level of nitrogen inputs was calculated for each crop grouping using the lowest value in the ranges used in Table 5.14. The estimate of moderate inputs used values from both ends of the ranges of lbs N/ac/yr for each crop group. The low and high calculations represent a best case and worst case analysis. It is not likely that all growers would use the highest rates all in the same year or the lowest rates in a different year and data collected by PVWMA validates this statement. Therefore, the most appropriate assumption of nitrogen inputs is the moderate level where the known ranges of fertilizer use are applied to fractions of each crop grouping. The range of nitrogen input values from fertilizer based on the described methodology is in Table 5.15.

**Table 5.15:** Estimated nitrogen inputs from fertilizer applications.

| Relative inputs from fertilizer applications | N inputs (lbs N/ac/yr) |
|----------------------------------------------|------------------------|
| <b>HIGH</b>                                  | 207                    |
| <b>MOD</b>                                   | 178                    |
| <b>LOW</b>                                   | 149                    |

### 5.3.2.4 IRRIGATION INPUTS

#### IRRIGATION WATER NITRATE CONCENTRATIONS

Average irrigated nitrate-NO<sub>3</sub> concentration for agricultural lands was estimated using the average nitrate-NO<sub>3</sub> data from 310 groundwater wells sampled from 2002 to 2011 (Figure 4.8). The spatially weighted average concentration for the PVGB was estimated using an IDW raster map, identical to the methodology presented in Chapter 7.2 on Assimilative Capacity. The basin-wide average concentration

was estimated to be 28 nitrate-NO<sub>3</sub> mg/L. To represent a reasonable range of concentrations, low and high and estimates were calculated by taking  $\pm 20\%$  of the average estimated nitrate-NO<sub>3</sub> concentration of 28 mg/L, yielding values of 22 mg/L and 34 mg/L, respectively (Table 5.16). High and low estimates for groundwater irrigation rates are described in more detail below and are provided in Table 5.17.

**Table 5.16:** Estimated range of nitrate-NO<sub>3</sub> concentration in groundwater and nitrate-N inputs from irrigation water based on Figure 4.8 and an IDW raster map.

| Relative NO <sub>3</sub> groundwater concentration | Nitrate-NO <sub>3</sub> concentration in groundwater (mg/L) | Nitrate-N inputs from irrigation water (lbs/AF) |
|----------------------------------------------------|-------------------------------------------------------------|-------------------------------------------------|
| <b>HIGH</b>                                        | 34                                                          | 21                                              |
| <b>MOD</b>                                         | 28                                                          | 17                                              |
| <b>LOW</b>                                         | 22                                                          | 14                                              |

## IRRIGATION WATER USE INTENSITY

An estimate of the irrigation water use intensity based on the 2011/2012 Pajaro Valley land use was determined in order to estimate for nitrogen inputs from irrigation water specific to the Pajaro Valley. Annual water use for a particular crop type is dependent on a number of factors including rainfall, climate, and soil type with the assumption that general crop types and/or irrigation practices can be grouped into relative categories of anticipated average use rates. A number of data sources were considered to obtain a range of rates which should encompass the variability caused by the different factors listed above. These sources were:

1. PVWMA water usage data collected in 2011,
2. MCWRA water usage data collected in 2010 (MCWRA 2010),
3. Data collected by Central Coast U.C. Irrigation Farm Advisor (Cahn *et al.* 2011 and 2012) and
4. Published documents (Prichard *et al.* 1989, Righetti *et al.* 1998, Mahler and Barney 2000, Pettygrove 2003, Hart *et al.* 2006a and 2006b, Smith *et al.* 2008, LeStrange *et al.* 2010, Turini *et al.* 2010).

Three categorical thresholds for relative irrigation intensity were created to encompass the range of potential irrigation volumes applied to typical crops cultivated in the Pajaro Valley. Using the resources listed above and based on evaluation of irrigation practices over the last few years (2010-2013), the relative irrigation intensity categories are summarized in Table 5.17.

**Table 5.17:** Annual relative irrigation intensity based on the 2012 crop distribution (Table 5.12)

| Annual irrigation relative intensity | Irrigation method     | Crop Types                       | Estimated range of water use (AF/acre/yr) | Average water use (AF/acre/yr) | Agricultural area distribution (acres) | Area % of agricultural land |
|--------------------------------------|-----------------------|----------------------------------|-------------------------------------------|--------------------------------|----------------------------------------|-----------------------------|
| <b>High</b>                          | sprinkler or overhead | row crops, artichokes, nurseries | 2.4 to 3                                  | 2.7                            | 10,480                                 | 39%                         |
| <b>Moderate</b>                      | drip                  | cane berries, strawberries       | 1.8 to 2.3                                | 2.05                           | 12,990                                 | 49%                         |
| <b>Low</b>                           |                       | grapes, tree fruits              | 0.5 to 1.7                                | 1.1                            | 3,320                                  | 12%                         |
| Total agricultural land use          |                       |                                  |                                           |                                | 26,790                                 | 100%                        |

Low, moderate, and high estimates of irrigation intensity were derived from the categorical range and average estimated water use (Table 5.17). The data in Tables 5.16 and 5.17 and the methodology described above generated the following values of nitrogen input rates for irrigation water (Table 5.18).

**Table 5.18:** Estimated nitrogen inputs from irrigation.

| Relative input rates<br>from irrigation | Nitrate-N inputs<br>(lbs N/ac/yr) |
|-----------------------------------------|-----------------------------------|
| <b>HIGH</b>                             | 52                                |
| <b>MOD</b>                              | 38                                |
| <b>LOW</b>                              | 26                                |

### 5.3.2.5 ATMOSPHERIC DEPOSITION

Variations in wind patterns and population density strongly influence the deposition of nitrogen compounds from automobiles and industrial exhaust. Coastal and low population areas of California have relatively low atmospheric deposition rates (<3 lbs N/ac/yr). Whereas, the eastern Central Valley and San Joaquin Valleys have much higher rates (>10 lbs N/ac/yr) as a result of downstream air flow from metropolitan areas of San Francisco. Viers *et al.* (2012) used the EPA's Community Multiscale Air Quality (CMAQ) model with the highest spatial resolution grid available for California (4 km) and measured data (Tonnensen *et al.* 2007; Fenn *et al.*, 2011) to obtain an estimate of 5 lbs N/ac/yr for the Salinas Valley. Located along the coast and immediately north of the Salinas Valley, the Pajaro Valley is assumed to have a similar average atmospheric deposition rate of 5 lbs N/ac/yr as the Salinas Valley. As a reasonable estimate, low and high rates of nitrogen inputs from atmospheric sources was determined by taking  $\pm 20\%$  of the Salinas Valley average, yielding 4 N lbs/ac/yr and 6 N lbs/ac/yr, respectively (Table 5.19).

**Table 5.19:** Estimated range of nitrogen inputs from atmospheric sources for the Pajaro Valley based on modeled simulations for the California Central Valley

| Relative estimate of inputs from<br>atmospheric sources | Nitrogen inputs<br>lbs N/ac/yr |
|---------------------------------------------------------|--------------------------------|
| <b>HIGH</b>                                             | 6                              |
| <b>MOD</b>                                              | 5                              |
| <b>LOW</b>                                              | 4                              |

### 5.3.2.6 HARVESTED NITROGEN

Estimates of harvested nitrogen were obtained using the reported 2012 agricultural yields and the USDA's Crop Nutrient Tool (available online at [www.plants.usda.gov/npk/NutrientReport](http://www.plants.usda.gov/npk/NutrientReport)). The 2012 agricultural yields from Santa Cruz and Monterey Counties were reported by the ACR for each county (Santa Cruz County, 2012 Ag Report; Monterey County, 2012 Ag Report). The majority of the agricultural lands in Pajaro Valley are located within Santa Cruz County and thus this data was used as the primary resource. Data from Monterey County was used as supplementary information for estimating average harvested nitrogen from vegetable row crops because Santa Cruz County provided data for lettuce and Brussel sprouts only, and additional vegetable crops are regularly grown in the Pajaro Valley.

It should be noted that yields reported to the county Agricultural Commissioners are self-reported values and the estimated yields are highly influenced by amount of growers reporting, source of data generating yields for the growers (i.e., sales reports vs. carton receipts) and market conditions. In addition, the yield values supplied for 2012 were very moderate compared to other years. Viers *et al.* (2012) also mentions three different factors affecting yields that may significantly underestimate the amount of N removed by crops in California. These factors are accuracy of reported tonnage per acre, actual nutrient content of crops grown in California vs. other regions, and combining of yield data from the same crops grown under different conditions.

Table 5.20 provides high, moderate, and low estimates of harvested nitrogen by crop type. Six different vegetables were averaged to obtain an estimate of harvested nitrogen for vegetable row crops. Harvested nitrogen from cane berries was determined by the average of raspberries and blackberries. Moderate estimates of harvested nitrogen were obtained from the nutrient crop tool and actual reported yields; the high and low estimates of harvested nitrogen were estimated by taking  $\pm 20\%$  of the moderate value to present a reasonable range.

**Table 5.20:** Estimated range of harvested nitrogen for 2012 agricultural yields.

|            |                  | Estimated harvested nitrogen (lbs N/ac/yr) |       |       |
|------------|------------------|--------------------------------------------|-------|-------|
|            |                  | HIGH                                       | MOD*  | LOW   |
| Vegetables | Lettuce - head   | 91.0                                       | 75.8  | 60.6  |
|            | Lettuce - leaf   | 89.8                                       | 74.8  | 59.8  |
|            | Brussels Sprouts | 162.2                                      | 135.2 | 108.2 |
|            | Artichoke        | 64.4                                       | 53.7  | 43.0  |
|            | Carrot           | 93.2                                       | 77.66 | 62.1  |
|            | Broccoli         | 102.6                                      | 85.5  | 68.4  |
|            | Celery           | 125.0                                      | 104.2 | 83.4  |
| AVG VEG    |                  | 104.0                                      | 86.7  | 69.4  |
| Fruits     | Grapes - Wine    | 8.4                                        | 7     | 5.6   |
|            | Apple            | 32.8                                       | 27.3  | 21.8  |
|            | AVG TREE/VINE    | 20.6                                       | 17.2  | 13.7  |
|            | Strawberry       | 71.4                                       | 59.5  | 47.6  |
|            | Raspberries      | 34.1                                       | 28.4  | 22.7  |
|            | Blackberries     | 18.8                                       | 15.7  | 12.6  |
| AVG CANE   |                  | 26.5                                       | 22.1  | 17.6  |

\*moderate values were estimated from the USDA crop nutrient tool and the reported yields using default values for % moisture.

Similar to the methodology for the fertilizer and irrigation inputs, the relative acres of each crop group were used to generate potential values for high, moderate, and low harvested nitrogen rates. The estimated values using this approach are in Table 5.21.

**Table 5.21:** *Estimated range of nitrogen loss from harvested crops using crop reports and the USDA crop nutrient tool.*

| Relative nitrogen output<br>from harvested crops | Estimated nitrogen<br>removed<br>(lbs N/ac/yr) |
|--------------------------------------------------|------------------------------------------------|
| <b>HIGH</b>                                      | 66                                             |
| <b>MOD</b>                                       | 55                                             |
| <b>LOW</b>                                       | 44                                             |

### 5.3.2.7 SURFACE RUNOFF

Using USGS land use distributions for the Central Valley, Viers *et al.* (2012) estimated that surface runoff nitrogen losses to streams was on average 13 lbs N/ac/yr. Due to the potential variability in the amount of runoff from agriculture due to variability in drainage and irrigation intensity, high and low estimates are calculated as  $\pm 20\%$  of the average (Table 5.22).

**Table 5.22:** *Estimated range of nitrogen loss from surface runoff using model simulations for the Salinas and Central Valley.*

| Relative nitrogen output<br>from surface runoff | Estimated nitrogen<br>removed<br>lbs N/ac/yr |
|-------------------------------------------------|----------------------------------------------|
| <b>HIGH</b>                                     | 16                                           |
| <b>MOD</b>                                      | 13                                           |
| <b>LOW</b>                                      | 10                                           |

### 5.3.2.8 ATMOSPHERIC LOSSES

The term, atmospheric loss of nitrogen, includes denitrification and the transformation of nitrogen compounds to nitrogen gas in anoxic environments. Viers *et al.* (2012) estimated total nitrogen loss from nitrogen gases ( $N_2$ ,  $N_2O$ ,  $NH_3$ , and  $NO_x$ ) to be 10% of all N inputs using best available data for California and the U.S. Other researchers in California have also calculated a 10% atmospheric loss, but separated the contributions of human activities including agriculture vs. the effect of wetlands and other natural lands (Tomich, Thomas P., 2016). The 10% average atmospheric loss for California includes a relatively small amount of wetlands: 1.37% of all land in California (USDA, NRCS, 2010). In contrast, the PVGB has a substantial wetland area draining approximately 11,867 acres of farmland and open space (Watsonville Slough Hydrology Study, 2014). The permanently ponded area within the Watsonville Slough System is 549 acres and this is 2% of the total acres in agricultural production. In addition, studies on the slough system have documented conditions of very active denitrification (Schmidt *et al.*, 2011). Therefore, a different approach has been taken to estimate the amount of atmospheric nitrogen loss in the PVGB.

In situ studies in the Watsonville Slough System have documented an N load reduction of 6.2 lbs  $NO_3$ -N per day per acre of ponded area (Schmidt *et al.*, 2011). This rate is approximately double the average N load reduction observed in treatment wetlands (Kadlec and Wallace, 2009; Moreno-Mateos *et al.*, 2010). In this analysis, the lower reduction rate (3.1 lbs  $NO_3$ -N per day per ponded acre) is used to compensate for spatial and seasonal variability in N loading to the slough system. At this rate,

the ponded areas of the Watsonville Slough System annually remove 621,194 lbs of N. This total amount of N removal is 23 lbs N per acre of agricultural land per year. Due to the variability of various factors, we apply high and low nitrogen losses as 23 lbs N/acre per year  $\pm$  20% (Table 5.23).

**Table 5.23:** Estimated range of nitrogen loss to the atmosphere based on simulations for the Salinas and Central Valley.

| Relative nitrogen output from atmospheric losses | Estimated nitrogen removed lbs N/ac/yr |
|--------------------------------------------------|----------------------------------------|
| <b>HIGH</b>                                      | 28                                     |
| <b>MOD</b>                                       | 23                                     |
| <b>LOW</b>                                       | 19                                     |

### 5.3.2.9 NITROGEN LEACHING POTENTIAL TO GROUNDWATER FROM AGRICULTURE

The theoretical amount of nitrogen leaching to groundwater can be estimated by subtracting the nitrogen outputs (harvested, surface runoff, and atmospheric losses) from the nitrogen inputs (fertilizer application, irrigation water inputs, atmospheric deposition), as described by Equation 4. High, moderate, and low estimates were calculated by equations 1-3. The summary of nitrogen inputs and outputs resulting from agricultural practices is contained in Table 5.24.

**Table 5.24:** Estimated range of nitrogen inputs and outputs resulting from agricultural practices in the Pajaro Valley. See Tables 5.15, 5.18, 5.19, 5.21, 5.22, and 5.23.

|                                         |                        | Potential nitrogen mass per acre in agricultural production per year (lbs N/ac/yr) |            |             |
|-----------------------------------------|------------------------|------------------------------------------------------------------------------------|------------|-------------|
|                                         |                        | <b>HIGH</b>                                                                        | <b>MOD</b> | <b>LOW</b>  |
| <b>INPUTS</b>                           | Fertilizer application | 207                                                                                | 178        | 149         |
|                                         | Irrigation inputs      | 52                                                                                 | 38         | 26          |
|                                         | Atmospheric deposition | 6                                                                                  | 5          | 4           |
|                                         |                        | <b>LOW</b>                                                                         | <b>MOD</b> | <b>HIGH</b> |
| <b>OUTPUTS</b>                          | Harvested N            | 44                                                                                 | 55         | 66          |
|                                         | Surface runoff         | 10                                                                                 | 13         | 16          |
|                                         | Atmospheric losses     | 19                                                                                 | 23         | 28          |
|                                         |                        | <b>HIGH</b>                                                                        | <b>MOD</b> | <b>LOW</b>  |
| <b>Net N Potentially Leaching to GW</b> |                        | <b>192</b>                                                                         | <b>130</b> | <b>69</b>   |

Using these methods, the average annual estimated nitrogen leaching to groundwater from agricultural lands in the Pajaro Valley ranges from 69 to 192 lbs/acre/yr. Figure 5.17 shows the relative contribution of each input and output, as well as the range of potential leaching to groundwater from agricultural practices.

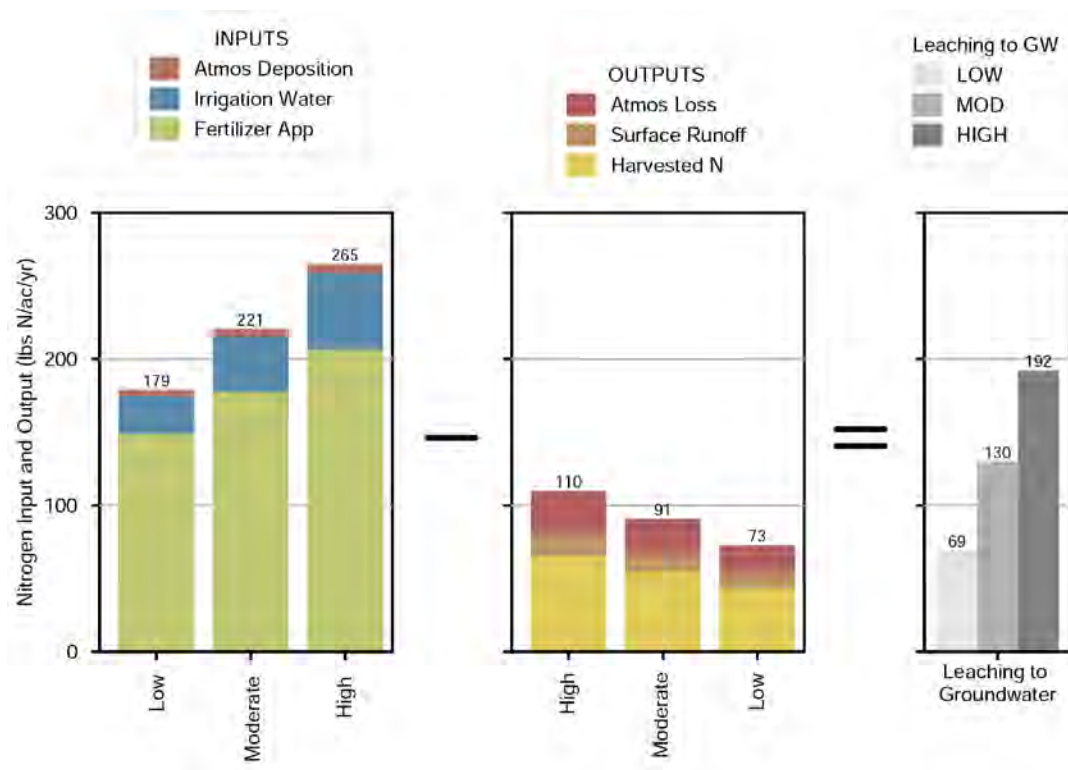


**Figure 5.17.** Modeled nitrogen loading to groundwater using inputs and outputs from agricultural practices.

In summary, based on the Viers model and current available information, Pajaro Valley agricultural lands could theoretically leach on average 130 lbs N/acre/yr to groundwater with a potential range of 69 to 192 lbs N/acre/yr. Given the approximate 26,790 acres of actively farmed land in the region, the total modeled nitrogen load from agriculture to groundwater on average annual basis is estimated to be 1,741 t N/yr, with a potential range of 924 to 2,572 t N/yr.

Using the average annual surface infiltration volume and model results, it is possible to estimate the nitrate concentration of water infiltrating via agricultural lands. The annual surface infiltration volume over agricultural lands can be estimated from the infiltration rate for the entire PVGB (46,280 AFY), scaled by the fraction of agricultural lands in the Pajaro Valley (39% of total). Using the nitrogen loads generated by the analysis, the estimated nitrate-NO<sub>3</sub> concentration of infiltrating water over agricultural lands is between 167 mg/L and 465 mg/L (Table 5.25).

**Table 5.25:** Estimated range of nitrogen concentrations in infiltrating water over agricultural lands.

| Units                              | Range of nitrogen loading converted to mg/L |            |            |
|------------------------------------|---------------------------------------------|------------|------------|
|                                    | HIGH                                        | MOD        | LOW        |
| Lbs N/ac/yr                        | 192                                         | 130        | 69         |
| Total T N/ac/yr                    | 2572                                        | 1741       | 924        |
| Total AF                           | 18,049                                      | 18,049     | 18,049     |
| NO <sub>3</sub> -N mg/L            | 105                                         | 71         | 38         |
| <b>Nitrate-NO<sub>3</sub> mg/L</b> | <b>465</b>                                  | <b>315</b> | <b>167</b> |

### 5.3.2.10 COMPARISON TO MEASURED DATA

In order to assess the reasonableness of the magnitude of these estimates, it is important to reference the organic N reservoir and review data collected by PVWMA that relates to potential nitrate leaching. As previously stated, the organic N reservoir in the Pajaro Valley is estimated to be over 26,000 pounds (13 tons) per acre from 0 to 2 feet below the surface. The addition of 69 – 192 lbs N/acre/yr is potentially an addition to the organic N reservoir of only 0.3 to 0.7%.

Some amount of this additional N is plant residues incorporated into the soil and adding to the organic N reservoir until they are converted to nitrate-NO<sub>3</sub>. As previously mentioned, the Viers *et al.* (2012) model did not calculate plant residue additions to the organic N reservoir or rates of conversion of organic N to nitrate-NO<sub>3</sub>. Data from a soil study initiated by PVWMA in 2005 to study the long-term effect of recycled water and fertilizers applied within the Pajaro Valley and DWZ are presented below in order to assess the validity of the estimated nitrogen leaching. Six sites have been sampled three times annually to various depths in the soil profile to assess salt and nitrogen loads with the use of delivered water and average growing practices (Platts, 2015). Additional information on the soil monitoring program is contained in Chapter 9. Table 5.26 contains the nitrate data from 24-36" depth profile which is below the rooting depth of the crops grown and the organic N reservoir and would be indicative of levels of salt and nutrient migration into groundwater. As the table shows, there are variable and low to moderate levels of nitrate-NO<sub>3</sub> below the crop rooting depth and organic N reservoir.

**Table 5.26:** Average soil nitrate-N and nitrate-NO<sub>3</sub> concentrations at 24-36" depth, 2005-2015

| Location  | Average Nitrate-N<br>(mg/L) | Average Nitrate-NO <sub>3</sub><br>(mg/L) | Number of<br>samples |
|-----------|-----------------------------|-------------------------------------------|----------------------|
| Site 1    | 7.52                        | 33.3                                      | 26                   |
| Site 2    | 6.34                        | 28.1                                      | 26                   |
| Site 3    | 4.24                        | 18.8                                      | 26                   |
| Site 4    | 13.90                       | 61.6                                      | 20                   |
| Site 5    | 6.12                        | 27.1                                      | 18                   |
| Site 6    | 6.43                        | 28.5                                      | 18                   |
| All Sites | 7.27 (weighted average)     | 32.2 (weighted average)                   | 134                  |

In addition to the soil study data, sampling data has been collected in monitoring wells located close to the soil monitoring sites. These data are collected annually within the coastal zone (see Chapter 9 for additional information on monitoring programs). The following table is from an annual report filed by PVWMA to the Regional Board. The table shows that the changes in concentration of nitrate-NO<sub>3</sub> have been extremely gradual over the last 15 years and that the number of samples with no detectable nitrate has been increasing since 2011.

**Table 5.27:** Annual average nitrate-NO<sub>3</sub> (mg/L) concentrations from PVWMA monitoring wells in the Coastal Area (2015 PVWMA Master Reclamation Permit, Annual Report to CCRWQCB).

| Year             | Number of samples | Average Nitrate-NO <sub>3</sub> (mg/L) | % Non-detect results | Sampling method      |
|------------------|-------------------|----------------------------------------|----------------------|----------------------|
| <b>2000-2008</b> | 75                | 19                                     | 32%                  | Manual airlift       |
| <b>2010</b>      | 13                | 17                                     | 61%                  | Portable micro purge |
| <b>2011</b>      | 43                | 29                                     | 32%                  | Low flow sampling    |
| <b>2012</b>      | 73                | 35                                     | 42%                  | Low flow sampling    |
| <b>2013</b>      | 67                | 38                                     | 48%                  | Low flow sampling    |
| <b>2014</b>      | 42                | 39                                     | 52%                  | Low flow sampling    |

The results in Table 5.27 align with the average PVGB nitrate-NO<sub>3</sub> concentration of 28 mg/l (Table 4.4). As presented in Tables 4.4, 5.26 and 5.27, these observed groundwater concentrations are significantly lower than the estimated concentrations based on the loading analysis (167-465 mg/L; see Table 5.26). Levels in this estimated range infiltrating annually over the last decade would likely create an average concentration greater than 28 mg/L (Table 4.4) and significantly affect the average concentrations measured in the monitoring wells (ranging from 17 – 39 mg/L, Table 5.27). In addition, data from the soil study indicates much lower levels of nitrate-NO<sub>3</sub> (average of 32 mg/L) below the rooting zone and the organic N reservoir. While it can be expected that the current measured nitrate concentrations in groundwater would be lower than the estimated infiltrating nitrate-NO<sub>3</sub> concentrations due to dilution and various other hydrologic factors, significant nitrogen retention in the organic N reservoir and rates of less than total conversion to nitrate are possible factors as well.

In summary, a high quality dataset was utilized within a moderately complex model to estimate the potential nitrogen load to groundwater generated by agricultural production within the PVGB. The exclusion of several critical variables within the model and the theoretical nature of these estimates results in overestimates of the level of nitrate leaching, as corroborated by data collected by PVWMA. The most appropriate uses of the estimates generated by this analysis are comparative uses to other datasets and over time within the PVGB. It would be inappropriate to generate regulations for agriculture based on these modeled estimates.

### 5.3.3 SEWER SYSTEM NITROGEN LOADING POTENTIAL

Spatial data documenting existing locations of sewer lateral and transfer lines within the PVGB were obtained from the City of Watsonville GIS department and Pajaro County Sanitation District (PCSD). There were no GIS data associated with PCSD sewer lines, so existing AutoCAD layout sheets were interpreted by 2NDNATURE to digitize sewer line locations in GIS. Figure 5.18 presents the location of existing sewer lines within the basin. All sewage in the basin is routed to the Watsonville Wastewater Treatment Plant located off West Beach Street servicing 8.5 square miles, approximately 55,000 people, treating an average of 5.3 million gallons per day based on 2011/2012 practices.

The relative potential magnitude of annual nitrogen loading to the groundwater from sewage exfiltration is assumed to be dependent on the probability and/or annual amount of leakage and the soil water holding capacity, with low saturation soils having a high threat of vertical migration of nutrients released from sewage. The probability of leakage or exfiltration could be estimated based on age of lines, time since last retrofits or repairs, recent integrity test results, or other spatially explicit information on relative condition of sewer lines.

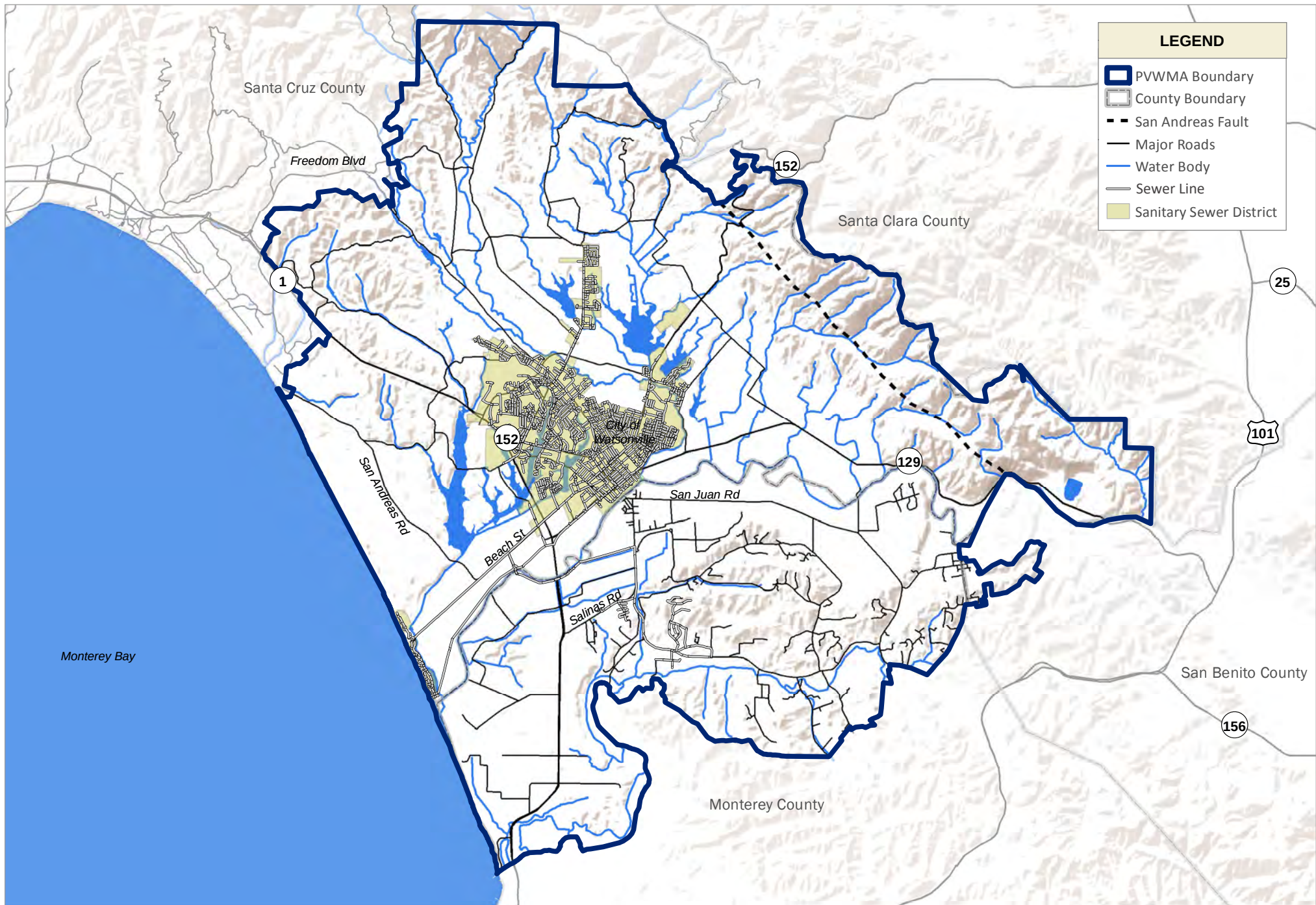


FIGURE 5.18: Existing (2012) sewer lines provided by City of Watsonville and Pajaro County Sanitation District.

Information regarding sewer system age, integrity or other potential information was not available. Figure 5.19 shows reported Sanitary Sewer Overflows (SSOs) in the urban area from 2007-2013, indicating a number of recent sewage leakages have occurred. SSOs include any leakage, spill, overflow, or other discharge of sewage from sanitary sewer systems. Category 1 SSOs are those where discharge of wastewater reaches the surface water or where the discharge water reaches a separate storm sewer system and is not fully captured. Category 2 SSOs are those that spill at least 1,000 gallons, but does not reach the surface water or municipal separate storm water system. Category 3 SSOs are all other overflows (SWRCB, 2015).

Nitrogen loading to groundwater from sewage leaking can be estimated from the average nitrogen excretion rate per capita along with the average municipal sewer leakage rates. Viers *et al.* (2012) relied upon a national data municipal sewer system leakage rate range from 1% to 25%. For the Pajaro Valley, this range provides the low and high end estimates for nitrogen loading from sewer. Given that an average nitrogen excretion rate per capita is 13.3 g N/capita/day and that the Watsonville Wastewater Treatment Plant (WWTP) treats an estimated 55,000 people, a high end estimate of annual nitrogen leaching to groundwater is 67 t N/yr (or an average 27.1 lbs N/acre/yr for the service area) and a low end estimate is 3 t N/yr (or an average of 1.1 lbs N/acre/yr for the service area) (Table 5.28).

**Table 5.28:** Range of nitrogen loading by sewer leakage rates

| Estimated leakage rate<br>from sewer systems<br>(% of total) | Estimated nitrogen load to<br>groundwater from leaking<br>sewer systems (t N/yr) | Estimated nitrogen load<br>within sewer service area<br>(lbs N/ac/yr) |
|--------------------------------------------------------------|----------------------------------------------------------------------------------|-----------------------------------------------------------------------|
| <b>HIGH (25%)</b>                                            | 67                                                                               | 27.1                                                                  |
| <b>MOD (13%)</b>                                             | 35                                                                               | 14.1                                                                  |
| <b>LOW (1%)</b>                                              | 3                                                                                | 1.1                                                                   |

### 5.3.4 SEPTIC SYSTEM NITROGEN LOADING POTENTIAL

Locations of septic systems were obtained from the County of Santa Cruz Environmental Health Services Department (EHS) and Monterey County EHS Department. The level of ongoing data management and quality differs between the two counties, with Santa Cruz having an active data management program including locations, failures, age, and pump dates. In contrast, Monterey County retains spatial information using a private consulting company and did not have access to the data at time of request. Maps provided by Monterey County EHS using database outputs illustrated which parcels in the county contained septic system permits. These maps were used by 2NDNATURE to digitize these septic locations in GIS.

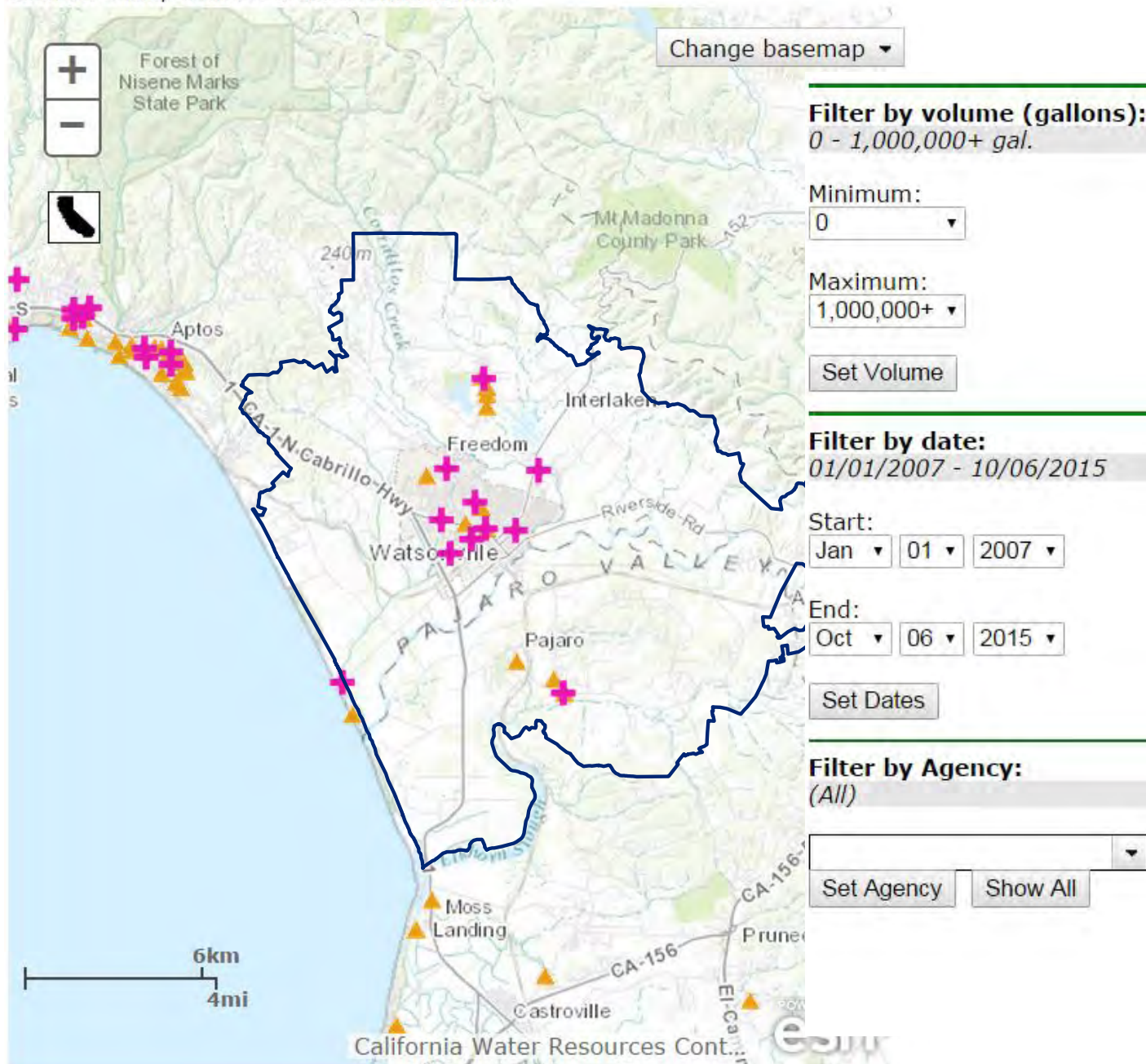
Figure 5.20 presents the distribution of the 4,472 existing septic systems within the Pajaro Valley (3,289 in Santa Cruz Co and 1,183 in Monterey County) and is used to map the relative density of septic systems in the area. The U.S. EPA (USEPA 1977) reports a threshold of 40 septic systems per square mile or more as “relatively high”. In comparison, the average septic density within the Pajaro Valley is 30 septic tanks/sq mi, with the densities as high as 425 septic units/sq mi within Freedom, Corralitos and Las Lomas. Breaks in the septic system density are made at 10, 40, and 80 tanks per square mile, which is consistent with the mapping efforts presented in Viers *et al.* (2012).

Nitrogen loading to groundwater from septic systems, or the nitrogen leakage rate, can be estimated by using nitrogen loading per capita and the percent nitrogen removal. Informed estimates of percent

## SANITARY SEWER OVERFLOWS: 01/01/2007 - 10/06/2015

Spill type: + [Category 1](#) ● [Category 2](#) ▲ [Category 3](#) [More Info](#)

Click on a map icon for incident information.



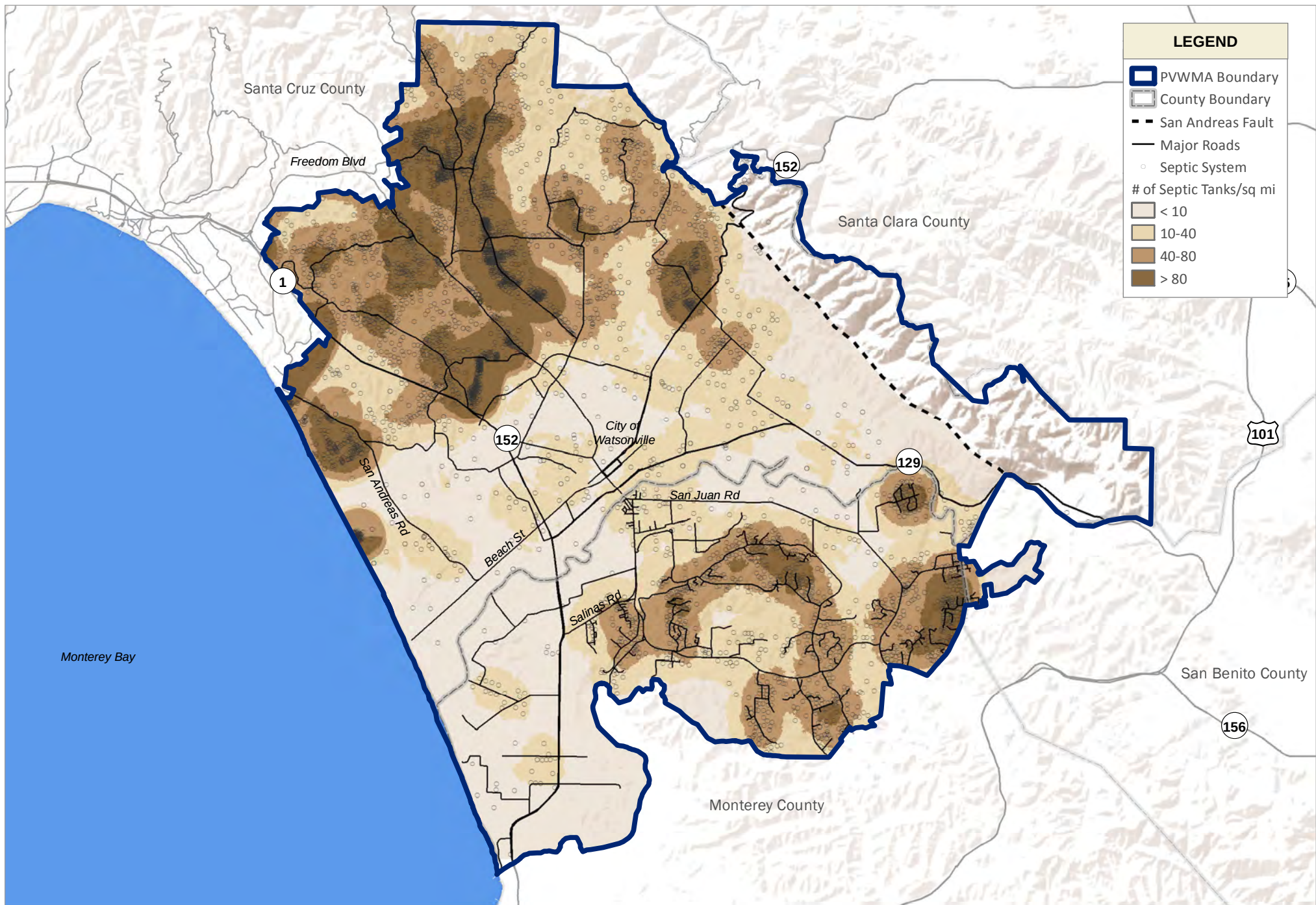


FIGURE 5.20: Location of existing septic systems and septic system density within the PVWMA boundary. Mapping of existing conditions (2012) was provided by Santa Cruz and Monterey County and the separation of septic tank density classes follows that of Viers et al. (2012).

nitrogen removal were based on extensive work from the neighboring San Lorenzo Watershed using shallow monitoring wells, lysimeters, and calibrated nitrogen budgets. For the San Lorenzo Watershed, 15-20% nitrogen removal in sandy soils was observed compared to non-sandy soils which showed 25-50% nitrogen removal (Ricker, J. personal communication, Sept 2015). These percent removal rates were applied to the Pajaro Valley based on the distribution of well-draining and poorly-draining soils in the area using the USDA hydrologic soil group (HSG) classification. Based on the USDA classification, approximately 53% of the soils in the Pajaro Valley are well-draining (HSG A & B) and 47% are poorly-draining soils (HSG C & D). The range in the estimated amount of nitrogen removed by soil type was used to determine the relative leakage rate from septic systems (Table 5.29). For comparison, Viers *et al.* (2012) reported that septic systems retain 15% of the total nitrogen delivered, a rate that resembles the percent nitrogen removal in sandy soils.

**Table 5.29:** Range of nitrogen removal and leakage rates by HSG soil types

| Relative estimated leakage rate from septic systems | % nitrogen removal for well-draining, sandy soils (HSG A&B) | % nitrogen removal for poorly-draining soils (HSG C&D) | % nitrogen removal for Pajaro Valley based on soil type |
|-----------------------------------------------------|-------------------------------------------------------------|--------------------------------------------------------|---------------------------------------------------------|
| <b>HIGH</b>                                         | 15%                                                         | 25%                                                    | 20%                                                     |
| <b>MOD</b>                                          | 18%                                                         | 38%                                                    | 27%                                                     |
| <b>LOW</b>                                          | 20%                                                         | 50%                                                    | 34%                                                     |

Based on the septic densities defined in Figure 5.20 and assuming an average household of 3.6 persons (US Census City of Watsonville 2010) with an estimated loading of 13.3 g N/capita/day, the estimated nitrogen loading to groundwater is given in Table 5.30. A low and high annual load of 49 to 60 t N/yr from septic systems is estimated.

**Table 5.30:** Low and high nitrogen loading by septic density, as shown in Figure 5.20

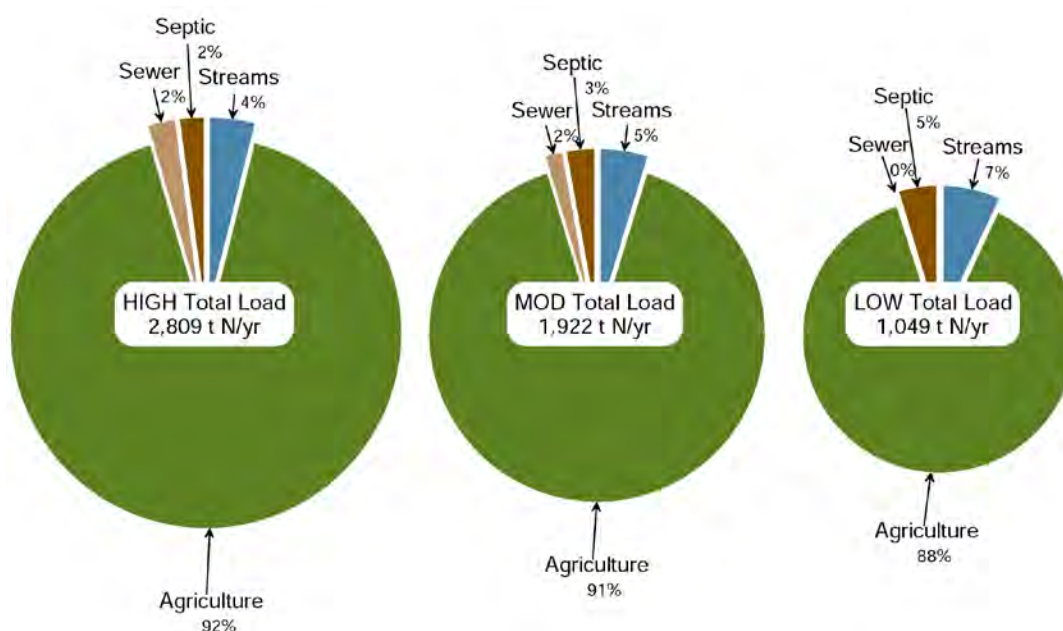
| Septic Density (#/sq mi)   | Area distribution (acres; %) | Mean septic density (#/sq mi) | People on septic (#/sq mi) | Estimated nitrogen loading from septic systems (lbs N/acre/yr) |           |           |
|----------------------------|------------------------------|-------------------------------|----------------------------|----------------------------------------------------------------|-----------|-----------|
|                            |                              |                               |                            | HIGH                                                           | MOD       | LOW       |
| <10                        | 22,872; 32%                  | 5                             | 18                         | 0.2                                                            | 0.2       | 0.2       |
| 10 – 40                    | 22,472; 31%                  | 25                            | 90                         | 1.2                                                            | 1.1       | 1.0       |
| 40 – 80                    | 16,640; 23%                  | 60                            | 216                        | 2.9                                                            | 2.6       | 2.4       |
| >80                        | 10,108; 14%                  | 80                            | 288                        | 3.9                                                            | 3.5       | 3.2       |
| <b>Total Load (t N/yr)</b> |                              |                               |                            | <b>60</b>                                                      | <b>55</b> | <b>49</b> |

### 5.3.5 PVGB NITRATE LOADING POTENTIAL

Based on the above estimates for most likely sources of N to groundwater (agriculture, sewer, septic, and streams) the total estimated tons of nitrogen per year that could theoretically leach to groundwater on an average annual basis is between 1,049 to 2,809 t N/yr (Table 5.31 and Figure 5.21). Given these estimates, the primary source is direct infiltration via agricultural land uses. While these estimates are based on a theoretical calculation, the relative significance of agricultural practices on potential nitrogen loading to groundwater identified in the Pajaro Valley is consistent with the Viers *et al.* (2012) finding that over 90% of all nitrogen that could theoretically leach to groundwater is derived from agricultural sources.

**Table 5.31:** Summary of annual nitrogen leaching to groundwater estimates for Pajaro Valley priority sources.

| Nitrogen Source              | Average annual nitrogen load to groundwater<br>t N/yr ; % of total |              |              |
|------------------------------|--------------------------------------------------------------------|--------------|--------------|
|                              | HIGH                                                               | MOD          | LOW          |
| Agricultural land use        | 2,572; 92%                                                         | 1,741; 91%   | 924; 88%     |
| Sewer systems                | 67; 2%                                                             | 35; 2%       | 3; 0%        |
| Septic systems               | 60; 2%                                                             | 55; 3%       | 49; 5%       |
| Streams                      | 110; 4%                                                            | 91; 5%       | 73; 7%       |
| <b>Total N Load (t N/yr)</b> | <b>2,809</b>                                                       | <b>1,922</b> | <b>1,049</b> |

**Figure 5.21.** Total potential nitrogen loading to groundwater from surface and stream infiltration.

It should be noted that the sewer, septic, and stream sources of nitrogen encompass the entire PVGB acreage. In order to be consistent with the other nitrogen loading estimates, the total nitrogen load contributed by agriculture should be evaluated in comparison to the entire land area of the PVGB (Table 5.32).

A basin wide calculation of the potential nitrogen load per acre ranges from a best case scenario of 29 lbs NO<sub>3</sub>-N per acre to a worst case scenario of 78 lbs. This is a more accurate perspective of the nitrogen loading situation in a closed basin like the PVGB. These numbers are a benchmark for comparison in the future given the potential for changes in agricultural practices (land use, cropping patterns, fertilizer and water usage), population density (sewer and septic factors), and climate change (stream infiltration factor).

**Table 5.32:** Estimates of potential annual nitrogen load per acre to groundwater for Pajaro Valley priority sources.

| Nitrogen Source                      | Average annual nitrogen load to groundwater<br>lbs N/ac/yr ; % of total |           |           |
|--------------------------------------|-------------------------------------------------------------------------|-----------|-----------|
|                                      | HIGH                                                                    | MOD       | LOW       |
| Agricultural land use                | 71; 92%                                                                 | 48; 91%   | 26; 88%   |
| Sewer systems                        | 2; 2%                                                                   | 1; 2%     | 0; 0%     |
| Septic systems                       | 2; 2%                                                                   | 2; 3%     | 1; 5%     |
| Streams                              | 3; 4%                                                                   | 3; 5%     | 2; 7%     |
| <b>Total N Load<br/>lbs N/ac/yr)</b> | <b>78</b>                                                               | <b>53</b> | <b>29</b> |

The nitrate-NO<sub>3</sub> concentrations of water infiltrating the entire PVGB can be calculated from this data. Using the nitrogen loads generated by the analysis, the estimated nitrate-NO<sub>3</sub> concentration of infiltrating water over the entire PVGB area is between 74 mg/L and 198 mg/L. These estimates are a simple average for the basin. In areas without agricultural production (where sewer, septic, and streams are the only source of nitrogen), the estimated nitrate-NO<sub>3</sub> concentrations range from 8 mg/L to 18 mg/L. These estimates align with the nitrate groundwater data presented for nitrate in Chapters 4 and 7 (Tables 4.4 and 7.6) and are corroborated by the soil and monitoring well data reviewed earlier in this chapter.

## SUMMARY

Consistent with other regional, state, and national findings, agricultural land management practices in the Pajaro Valley are the primary source of nutrients affecting the groundwater basin, and after seawater intrusion, the main source of salts. A series of salt and nutrient loading comparisons have been created based on best available local data, research and estimated relative potential of leaching to groundwater from each source.

In general, the implementation of effective practices and programs to provide alternative irrigation water supplies and increased groundwater recharge rates and volumes are expected to eliminate overdraft and thus the rate of seawater migration inland. Streamflow infiltration of water with elevated salinity flowing from the upper Pajaro River watershed results in relatively high but localized salt loading generally along the reach of the Pajaro River between Chittenden Gap and Murphy Crossing.

While limitations to this approach exist and have been articulated throughout Chapter 5.3.2, this analysis does provide a comparable quantification of the sources of nitrogen potentially affecting the groundwater of PVGB. The nitrogen loading to groundwater analysis suggests 88 to 92% of the annual nitrogen load to groundwater is generated from agricultural land within the Pajaro Valley. Septic and sewer contributions as well as other relatively insignificant sources, such as urban runoff and atmospheric deposition, comprise the remaining 8-12% of the theoretical annual nitrogen loading to groundwater in the Pajaro Valley. On a relative scale, agricultural practices (Figure 5.15) located in relative high recharge zones (Figure 5.8) are likely to contribute a greater proportion of the agriculturally derived nitrogen load to groundwater, and future programs to increase the use of sustainable land management practices in these locations may prove beneficial.

## 6 SNMP GOALS AND OBJECTIVES

The Recycled Water Policy adopted by the State Water Resources Control Board in February 2009 states the following goals for the State of California:

- Increase the use of recycled water over 2002 levels by at least one million acre-feet per year (afy) by 2020 and by at least two million afy by 2030.
- Increase the use of stormwater over 2007 levels by at least 500,000 afy by 2020 and by at least one million afy by 2030.
- Increase the amount of water conserved in urban and industrial uses in comparison to 2007 by at least 20% by 2020.
- Included in these goals is the substitution of as much recycled water for potable water as possible by 2030.

The Recycled Water Policy also states “salts and nutrients from all sources be managed on a basin-wide or watershed-wide basis in a manner that ensures attainment of water quality objective and protection of beneficial uses” through the “development of regional or sub-regional salt and nutrient management plans.”

Separately, the PVWMA, through a stakeholder driven process, developed and adopted a Basin Management Plan Update in 2014, and certified a supporting programmatic Environmental Impact Report. The BMP is the foundation of the Agency’s efforts to efficiently and economically manage existing and supplemental water supplies in order to prevent further increase in, and to accomplish continued reduction of, long-term overdraft. The BMP describes the projects and programs that are being implemented in order to balance the groundwater basin and stop seawater intrusion. Planned projects that put local surface water supplies to beneficial use, optimize the use of existing water supply facilities, and implement a robust water conservation / irrigation efficiency program, will result in decreasing groundwater production within the overdrafted PVGB. These projects and programs will also have a beneficial impact on groundwater quality. For example, the single largest input of salt to the PVGB is from seawater intrusion, and stopping seawater intrusion is one of the primary objectives of the BMP. Implementation of the BMP’s projects and programs helps to improve groundwater quality.

The SNMP goals and objectives build off the adopted BMP. With the continued implementation of the BMP, groundwater production is decreasing because of increased supplemental water supply use and improved irrigation efficiency resulting from water conservation programs. Improved irrigation efficiency and nutrient management practices lead to a reduction in salt and nutrient loading from irrigation practices. The comparison between existing conditions documented in this report and future conditions will provide a measure of the success of the SNMP and BMP Update. The goals and objectives described below align with key components of the Agency’s BMP Update (2014), the Pajaro River IRWM, and the Regional Water Quality Control Basin Plan.

### 6.1 Goals

**GOAL #1:** Prevent further increase of groundwater overdraft and work toward continued reduction of groundwater overdraft through implementation of water supply facilities and water conservation programs. Improving groundwater quality in the PVGB starts with reducing groundwater overdraft. Groundwater storage depletion leads to a concentration of salts and

nutrients within the basin. Decreasing groundwater production and increasing recharge, however, will ultimately lead to dilution of salts and nutrients.

**GOAL #2:** Manage the groundwater basin to reduce and ultimately prevent groundwater quality degradation associated with salts and nutrients. BMP implementation provides funding for irrigation efficiency programs that provide the agricultural and residential communities with resources to help reduce the loading of salts and nutrients to the basin.

**GOAL #3:** Work with IRWM partners to improve source water quality by reducing surface water degradation in the upper watershed, while working with stakeholders locally to reduce surface water degradation within the lower watershed.

**GOAL #4:** Preserve agricultural production and provide support for growers implementing nutrient best management practices. BMP implementation provides funding for irrigation efficiency programs that provide technical support for growers, including access to UC Farm Advisors.

**GOAL #5:** Expand recycled water use. Recycled water is a safe and reliable alternative supply to groundwater. Increased recycled water use means less groundwater use, which helps to reduce both groundwater overdraft and seawater intrusion.

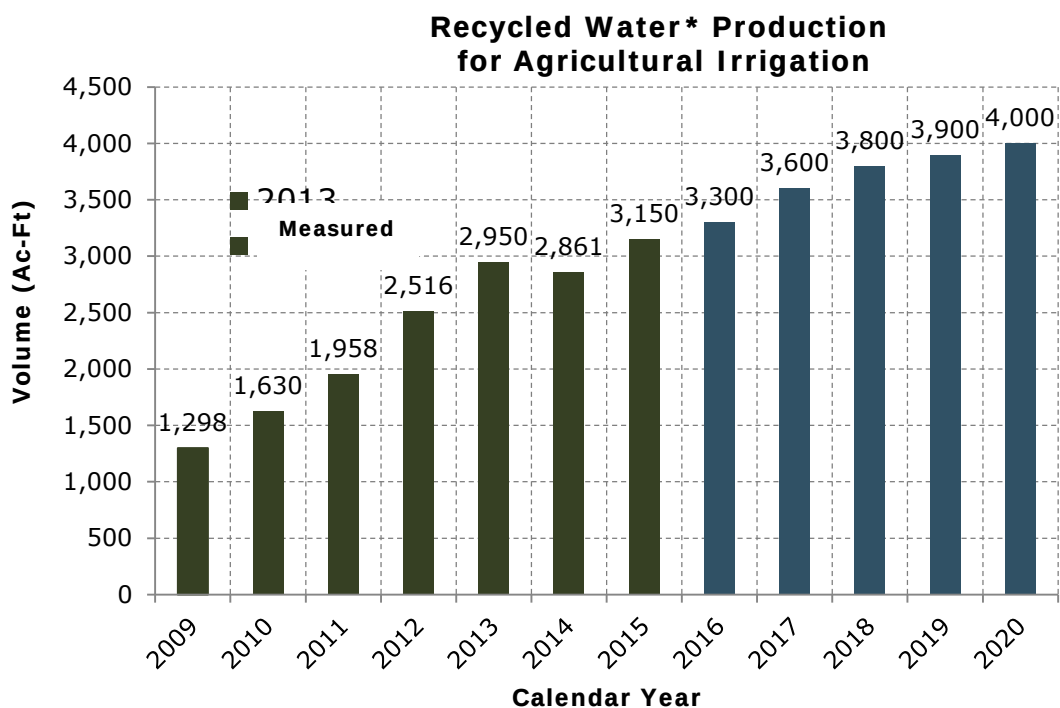
**GOAL #6:** Put storm water runoff to beneficial use through capture, treatment, and recharge. This goal will increase the recharge of high quality rainwater into the groundwater basin, which helps to reduce both groundwater overdraft and seawater intrusion.

**GOAL #7:** Improve understanding of salt and nutrient interactions between surface water and groundwater.

## 6.2 Objectives

### *A. Optimize the production and use of recycled water within the Pajaro Valley.*

This objective directly complements the State's goal to increase the use of recycled water by 2020 (Figure 6.1). The Recycled Water Facility has been operational since 2009 and was designed to produce 4,000 AFY of recycled water. Since 2009, the recycled water production has increased at an average rate 22% per year. This objective will be met by increasing recycled water storage and increasing customer demand. Additional storage will allow staff to treat flows entering the Waste Water Treatment Plant at night when customer demand is low, and store the finished recycled water for distribution during the day when customer demand is high. A 1.5-million-gallon tank is currently under construction and is scheduled to be completed and operational by May 2017. An additional 0.5-million-gallon tank has been designed, and will be built should additional storage be found necessary. Increased customer demand will be met through a combination of recently completed new pipelines that extend the delivered water service area to an additional 180 irrigated acres of farmland overlying an area of significant seawater intrusion, along with outreach and education to increase usage in the service area.



\*Recycled Water Facility design capacity is 4,000 acre-feet per year (AFY).

**Figure 6.1:** Projected recycled water production through 2020.

***B. Increase managed aquifer recharge (reduce annual runoff to Monterey Bay) on agricultural, commercial, residential and public lands, where appropriate.***

This objective ties in with the State's goal to increase the use of stormwater. The BMP Update includes a project to increase the annual diversion and recharge of water through the existing Harkins Slough Pump Station and Recharge Basin by 1,000 AFY when adequate flows exist. The BMP Update also includes two new managed aquifer recharge projects: 1) The Watsonville Slough with Recharge Basins project with an estimated yield of 1,200 AFY, and 2) the Murphy Crossing Diversion with Recharge Basins project on the Pajaro River, with an estimated yield of 500 AFY. In total, these three BMP Update projects would increase managed aquifer recharge by an estimated 2,700 AFY. In addition to the projects listed above, the PVWMA also supports the work being done by the Community Water Dialogue (CWD) in combination with the Resources Conservation District of Santa Cruz (RCDSCC) and the University of California, Santa Cruz (UCSC). The CWD has a goal of developing ten (10) recharge basins on the order of 1-2 acres in size that would capture local runoff and recharge it on the scale of 100 AFY per site for a total of about 1,000 AFY. In March 2016, the PVWMA Board of Directors approved a 5-year Recharge Net Metering Program that provides a financial incentive in the form of a rebate for water recharge by private land owners through basins approved by a Third Party Certifier (a combination of RCD and UCSC researchers). It is thought that this financial incentive, the first of its kind in the state, will provide motivation for the development of additional recharge basins. This work is supported by the "Managed Aquifer Recharge Suitability Study" ([Russo et al, 2014](#)), referred to in Chapter 5 and supported by PVWMA, which shows locations within the Pajaro Valley where recharge projects might be the most successful. The team has designed and built one project so far, and additional projects are in the planning and design phase. Reducing runoff and increasing recharge on the residential scale will come from conservation programs the Agency is implementing. Devices like

rain barrels will help to store rainfall runoff and put it to beneficial use, while rebates for graywater systems will encourage the reuse of water for household irrigation purposes.

***C. Increase agricultural water use efficiency and achieve the BMP Conservation Program goal of 5,000 ac ft/yr (10%) less water use by 2023 compared to 2006-2010 usage.***

This water use efficiency objective will be met through the implementation of an "On-Farm Irrigation Efficiency Program." The program consists of the following components:

- **Outreach to growers and residents through multiple avenues, including:**
    - The Agency's website through the launch of two new conservation toolkits, including one for agriculture and one for household water use.
    - Presenting and outreach at local events, stakeholder meetings, commodity groups, etc.
    - Existing venues including the Farm Bureau, the Strawberry Commission, the UC Ag. Extension, Community Water Dialogue and others.
  - **Partner collaboration and program coordination**
    - Support, leverage, and utilize the expertise of partners and their programs (RCDs, NRCS, UC Ag Ext, etc.)
    - Includes a program with the RCD-SCC that includes purchasing & loaning to growers wireless soil moisture monitoring devices (tensiometers) that help growers to keep irrigation events in the root zone, saving water and reducing the risk of fertilizer leaching to groundwater. The free trial, which comes with technical training, allows growers to try new technology at virtually no cost. If they decide to adopt the technology, rebates may be available subsidize the costs.
  - **Provide technical assistance and host irrigation efficiency workshops for growers on the following topics:**
    - Distribution uniformity, performance efficiency and system design,
    - Soil moisture monitoring,
    - Irrigation scheduling (including the use of Wireless Irrigation Systems), which in addition to conserving water, can help reduce nutrient loading by keeping nutrients within the root zone for plant uptake,
    - Additional beneficial on-farm practices that contribute to water conservation,
    - Benefits of using delivered water (including recycled water),
    - Sign-up assistance for financial incentive programs (e.g., NRCS EQIP)
    - Technical training for CropManage tools by experts.
  - **Increase efficiency of agricultural nutrient application programs. A reduction of the annual application of nutrients may be possible as determined by best management practices.**
  - **Implementation of the grant funded conservation programs such as the Drought Response Irrigation Efficiency Program (DRIP) and others that may be awarded.**
-

***D. Support Santa Cruz County, Monterey County, and San Benito County in their efforts to inspect septic systems and reduce nutrient outputs.***

- Existing agency rebate programs for Laundry to Landscape graywater reuse helps reduce septic flows.

***E. Conduct additional studies and perform analysis of existing data in order to improve understanding of salt and nutrient interactions between surface water and groundwater.***

## 7 ASSIMILATIVE CAPACITY

For the purpose of this SNMP, assimilative capacity is defined as the amount of loading the groundwater basin can receive from salts and nutrients without resulting in damage to aquatic life or humans who utilize and consume the water. Salt and nutrient groundwater assimilative capacity in the Pajaro Valley were based on the best estimate of existing conditions and regulatory standards. Assimilative capacity was determined by comparing the existing concentrations of the specific constituents of concern, total dissolved solids, chloride, and nitrate, to relevant Water Quality Objectives (WQO's). Given that no WQO's are explicitly stated for the PVGB in the current Water Quality Control Plan for the Central Coastal Basin ([Basin Plan](#), 2016), the thresholds defined for neighboring basins were used (Table 7.1). Groundwater with salt or nutrient concentrations exceeding stated thresholds was assumed to have no additional assimilative capacity.

**Table 7.1:** Assimilative capacity thresholds and rationale.

| Analyte                             | Assimilative Capacity Threshold (mg/L) | Rationale                                                                                                                             |
|-------------------------------------|----------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------|
| <b>Total Dissolved Solids (TDS)</b> | 1000                                   | Median groundwater objective for Pajaro River Basin for the Tres Pinos Sub-Area. (CCRWQCB, 2016)                                      |
| <b>Chloride (Cl)</b>                | 150                                    | Median groundwater objective for Pajaro River Basin at Hollister and Tres Pinos. (CCRWQCB, 2016)                                      |
| <b>Nitrate (NO<sub>3</sub>)</b>     | 45*                                    | EPA National Primary Drinking Water Regulations (2009)<br>*Converted documented standard to Nitrate-NO <sub>3</sub> using molar mass. |

### 7.1 Subarea Delineation

Stakeholders requested that the evaluation of assimilative capacity include multiple zones within the Pajaro Valley Groundwater Basin (PVGB). The CCRWQCB also supports the notion that assimilative capacity be evaluated within distinct subareas, using water quality, land use, institutional, or hydrogeological boundaries (CCRWQCB, 2014). Since there are no significant lateral hydrogeological barriers within the PVGB, the basin was divided into two zones based on the boundary for potential seawater intrusion (Figure 5.10). The boundary is parallel to the coast and one mile inland from the 2011 extent of seawater intrusion (Figure 7.1). It is based on the 30-year projection of seawater intrusion using historic rates. Zone 1 is the inland area, east of the boundary, and is not likely within the sphere of influence of seawater intrusion. The area to the west of the boundary is Zone 2, which represents where seawater intrusion is a concern currently or may be in the near future. Seawater intrusion has reduced the assimilative capacity for salts within coastal areas, and is the focus of numerous, ongoing management actions developed to mitigate inward migration, making the boundary between the two sub areas informative and relevant for potential future water use management actions.

### 7.2 Total Dissolved Solids (TDS)

The existing TDS groundwater concentrations in each zone were assessed using the average TDS data from 307 groundwater wells sampled from 2002 to 2011 (Figure 4.4). The spatially weighted average concentration for each zone was estimated using an inverse distance weighted (IDW) statistical interpolation raster map. Current conditions were compared to the threshold value of 1000 mg/L and the resulting assimilative capacity evaluation for each zone and the Basin is provided in Table 7.2 and Figure 7.2. Zone 1 has a remaining assimilative capacity of 534 mg/L TDS or 53%, whereas Zone 2

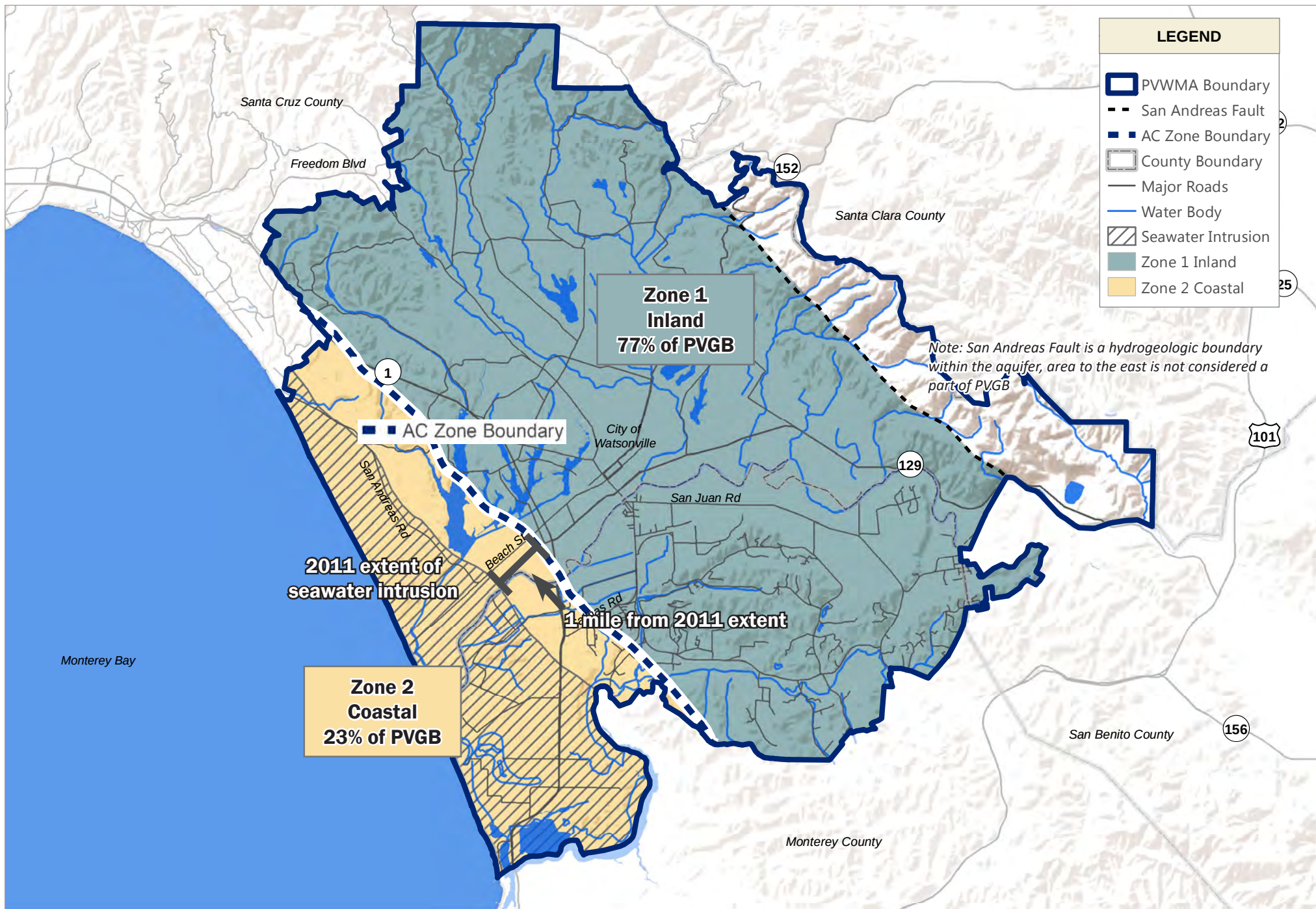


FIGURE 7.1: Assimilative capacity was assessed for two zones within the Pajaro Valley Groundwater Basin (PVGB). The boundary between zones is based on the historic rates of seawater intrusion, estimated as 1 mile from the 2011 extent of seawater intrusion.

has a remaining assimilative capacity of 270 mg/L TDS of 27%. Using Figure 4.4 and 4.5, specific areas where TDS is relatively elevated in Zone 1 are located along the eastern boundary where Highway 129 enters the valley. Elevated TDS groundwater concentrations in the Murphy's Crossing area are the result of infiltration of salt loaded river water into the highly permeable sediment underlying the channel. The coastal area (Zone 2) has higher concentrations of TDS (average 730 mg/L) than inland areas, which can be largely attributed to the historic seawater intrusion. Localized spikes of elevated average and maximum TDS concentrations can be seen in Figure 4.4 and 4.5. An exceedance analysis was also carried out to determine the distribution of sampled wells that had average TDS concentrations greater than the assimilative capacity threshold. A total of 15 wells within Zone 1 (11% of total) and 32 wells within Zone 2 (18% of total) had concentrations exceeding assimilative capacity (Table 7.3).

**Table 7.2:** Assimilative capacity for groundwater total dissolved solids.

| Total Dissolved Solids (TDS) Assimilative Capacity (AC) Threshold = 1000 (mg/L) |                |                              |                      |                  |
|---------------------------------------------------------------------------------|----------------|------------------------------|----------------------|------------------|
| PVGB Area                                                                       | % of PVGB Area | Average Concentration (mg/L) | Remaining AC* (mg/L) | Remaining AC (%) |
| Zone 1 (inland)                                                                 | 77%            | 466                          | 534                  | 53%              |
| Zone 2 (coastal)                                                                | 23%            | 730                          | 270                  | 27%              |
| PVGB Average                                                                    | 100%           | 527                          | 473                  | 47%              |

\*Remaining AC is the difference between the AC Threshold and the average concentration.

**Table 7.3:** Frequency that average TDS concentrations in sampled wells exceeded assimilative capacity.

| Total Dissolved Solids (TDS) Assimilative Capacity (AC) Threshold = 1000 (mg/L) |                    |                      |                      |                          |
|---------------------------------------------------------------------------------|--------------------|----------------------|----------------------|--------------------------|
| PVGB Area                                                                       | # of Wells Sampled | # Below AC Threshold | # above AC Threshold | % exceeding AC Threshold |
| Zone 1 (inland)                                                                 | 134                | 119                  | 15                   | 11%                      |
| Zone 2 (coastal)                                                                | 173                | 141                  | 32                   | 18%                      |
| PVGB (both zones)                                                               | 307                | 261                  | 47                   | 15%                      |

## 7.3 Chloride (Cl)

Using the boundaries explained in Chapter 7.1, the existing chloride groundwater concentrations in each zone was assessed using the average chloride data from 308 groundwater wells sampled from 2002 to 2011 (Figure 4.6). The spatially weighted average concentration for each zone was estimated using an IDW statistical interpolation raster map. Current conditions were compared to the threshold value of 150 mg/L and the resulting assimilative capacity evaluation is provided in Table 7.4. The analysis indicates that Zone 1 has 69% remaining assimilative capacity for chloride. However, the average chloride concentration of 198 mg/L in Zone 2 exceeds the defined threshold of 150 mg/L. Many locations within Zone 2 possess an even higher level of chloride, while in some areas the groundwater quality is less than the 150 mg/L AC threshold. Average and maximum groundwater chloride concentration maps (Figure 4.6 and 4.7) display areas where chloride concentrations exceed 500 mg/L. All of these areas fall within the 2011 extent of seawater intrusion front. An exceedance

analysis was also carried out to determine the distribution of sampled wells that had average chloride concentrations greater than the assimilative capacity threshold. Only one well within Zone 1 (less than 1% of total) exceeded the assimilative capacity threshold, while 45 wells in Zone 2 (26% of total) were greater than the assimilative capacity threshold (Table 7.5).

**Table 7.4:** Assimilative capacity for groundwater chloride.

| Chloride (Cl) Assimilative Capacity (AC) Threshold = 150 (mg/L) |                |                              |                      |                  |
|-----------------------------------------------------------------|----------------|------------------------------|----------------------|------------------|
|                                                                 | % of PVGB Area | Average Concentration (mg/L) | Remaining AC* (mg/L) | Remaining AC (%) |
| Zone 1 (inland)                                                 | 77%            | 46                           | 104                  | 69%              |
| Zone 2 (coastal)                                                | 23%            | 198                          | -48                  | -32%             |
| PVGB Average                                                    | 100%           | 83                           | 67                   | 45%              |

\*Remaining AC is the difference between the AC Threshold and the average concentration. Negative values suggest AC Threshold has been exceeded.

**Table 7.5:** Frequency that average chloride concentrations in sampled wells exceeded assimilative capacity.

| Chloride (Cl) Assimilative Capacity (AC) Threshold = 150 (mg/L) |                    |                      |                      |                          |
|-----------------------------------------------------------------|--------------------|----------------------|----------------------|--------------------------|
| PVGB Area                                                       | # of Wells Sampled | # Below AC Threshold | # above AC Threshold | % exceeding AC Threshold |
| Zone 1 (inland)                                                 | 135                | 134                  | 0                    | 0%                       |
| Zone 2 (coastal)                                                | 174                | 129                  | 45                   | 26%                      |
| PVGB (both zones)                                               | 308                | 262                  | 45                   | 15%                      |

## 7.4 Nitrate (NO<sub>3</sub>)

The existing nitrate-NO<sub>3</sub> groundwater concentrations in Zone 1 and 2 were assessed using the average nitrate data from 310 groundwater wells sampled from 2002 to 2011 (Figure 4.8). The spatially weighted average concentration for each zone was estimated using an IDW statistical interpolation raster map. Current conditions were compared to the threshold value of 45 mg/L and the resulting assimilative capacity evaluation is provided in Table 7.6 and Figure 7.2. Zone 1 had an average remaining assimilative capacity of 21 mg/L or 47%. Zone 2 had a higher average concentration for nitrate (39 mg/L with a remaining AC of 13%) than inland areas. Localized areas within Zone 1 and Zone 2 have average and maximum groundwater nitrate concentrations that are greater than the assimilative capacity threshold of 45 mg/L. These areas often correspond to locations identified with relatively high loading potential, resulting in elevated recharge rates. While nitrate concentrations do exceed assimilative capacity in certain locations, the PVGB as a whole still has 38% remaining assimilative capacity with regards to nitrate. An exceedance analysis was also carried out to determine the distribution of sampled wells that had average nitrate-NO<sub>3</sub> concentrations greater than the assimilative capacity threshold. A total of 24 wells within Zone 1 (18% of total) and 59 wells within Zone 2 (34% of total) had nitrate-NO<sub>3</sub> concentrations exceeding assimilative capacity (Table 7.7).

**Table 7.6:** Assimilative capacity for groundwater nitrate-NO<sub>3</sub>.

| Nitrate (NO <sub>3</sub> ) Assimilative Capacity (AC) Threshold = 45 (mg/L) |                |                              |                      |                  |
|-----------------------------------------------------------------------------|----------------|------------------------------|----------------------|------------------|
| PVGB Area                                                                   | % of PVGB Area | Average Concentration (mg/L) | Remaining AC* (mg/L) | Remaining AC (%) |
| Zone 1 (inland)                                                             | 77%            | 24                           | 21                   | 47%              |
| Zone 2 (coastal)                                                            | 23%            | 39                           | 6                    | 13%              |
| PVGB Average                                                                | 100%           | 28                           | 17                   | 38%              |

\*Remaining AC is the difference between the AC Threshold and the average concentration.

**Table 7.7:** Frequency that average nitrate concentrations in sampled wells exceeded assimilative capacity.

| Nitrate (NO <sub>3</sub> ) Assimilative Capacity (AC) Threshold = 45 (mg/L) |                    |                         |                      |                          |
|-----------------------------------------------------------------------------|--------------------|-------------------------|----------------------|--------------------------|
| PVGB Area                                                                   | # of Wells Sampled | # of Below AC Threshold | # Above AC Threshold | % exceeding AC Threshold |
| Zone 1 (inland)                                                             | 135                | 111                     | 24                   | 18%                      |
| Zone 2 (coastal)                                                            | 175                | 116                     | 59                   | 34%                      |
| PVGB (both zones)                                                           | 310                | 227                     | 83                   | 27%                      |

In summary, the amount of remaining assimilative capacity was evaluated for two sub-basins within the PVGB for each constituent of concern. While some monitoring wells exceeded the assimilative capacity threshold, nearly all areas met water quality objectives for assimilative capacity (Figure 7.2). The area that did not meet with water quality objectives was the coastal sub-basin which exceeded assimilative capacity for chloride. An exceedance analysis was carried out to determine the distribution of wells within each sub-basin that had average concentrations that exceeded assimilative capacity thresholds. On average, 27% of wells in the PVGB exceed assimilative capacity thresholds for each of the constituents of concern. For each constituent, the coastal zone had a greater percentage of wells exceeding assimilative capacity thresholds than the inland zone.

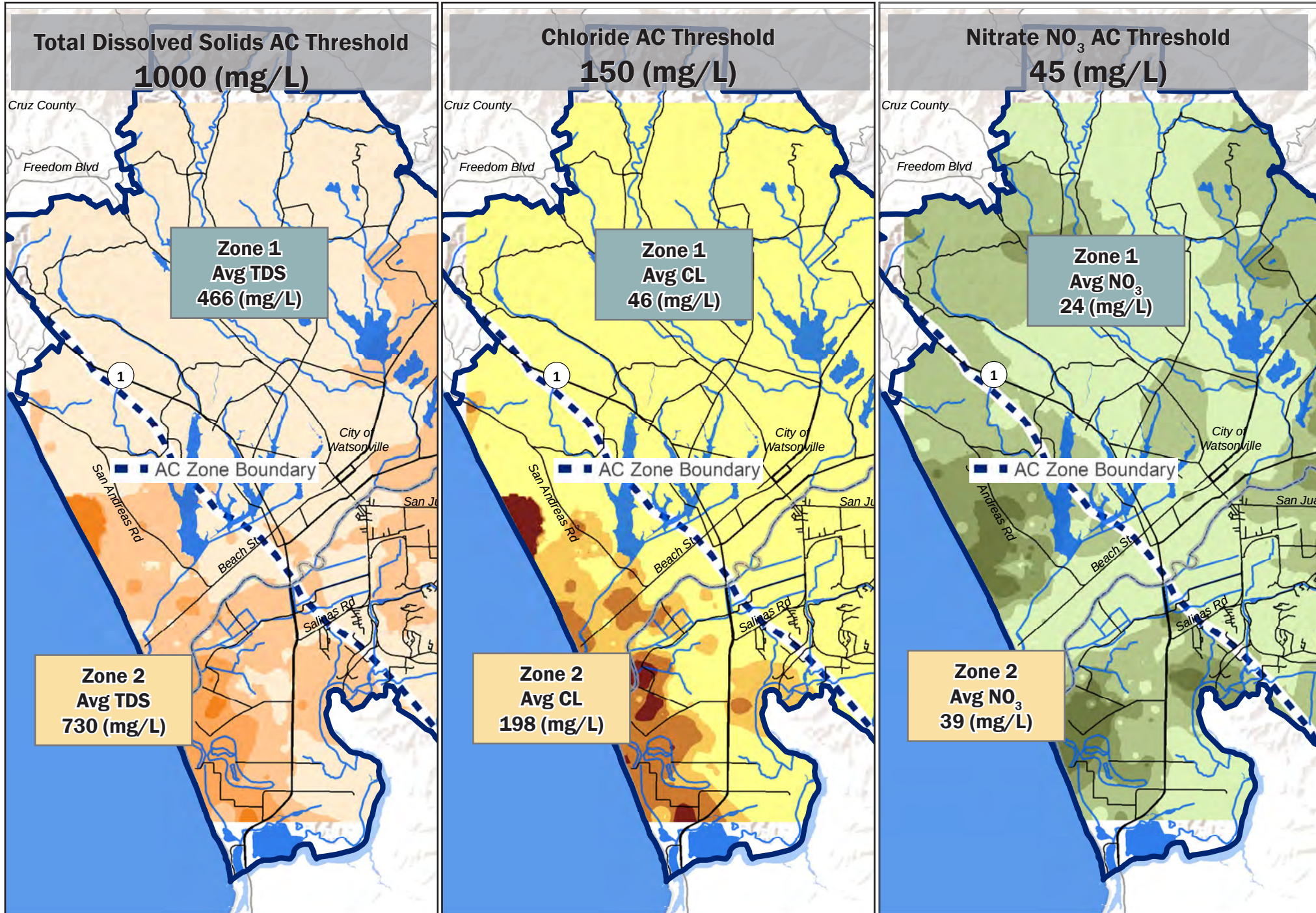


FIGURE 7.2: Average concentration values for each constituent, derived from concentration maps (4.4, 4.6, 4.8), are displayed for two zones within the PVGB. Zonal concentrations were calculated by taking average values of the inverse distance weighted concentration maps within each zone. Concentration values below the AC Threshold are considered to have remaining AC, while values above the AC threshold have exceeded AC.

## 8 DEVELOPMENT OF PRIORITY PROGRAMS

The Basin Management Plan (BMP) is the basis for priority projects and programs that the Agency implements. The BMP describes the water resources management approach to balancing the groundwater basin and stopping seawater intrusion that was decided by a stakeholder committee and approved by the board of directors. By design, the implementation of the BMP will improve the quality of groundwater within the basin and meet the objectives of the SNMP.

Under current conditions, the PVGB behaves much like a closed basin due to the occurrence of seawater intrusion along the coast and a hydrologic no-flow barrier caused by the San Andreas Fault system to the east. Groundwater from the northerly and southerly directions flow into the center of the PVGB. Groundwater containing higher than desired concentrations of salts and nutrients within the basin has no way to naturally flow out of the basin, but can be extracted via pumping. The overall groundwater quality will benefit from increased recharge of higher quality water sources, reduced rates of groundwater extraction, and irrigation efficiency programs. Irrigation efficiency programs are designed to help keep irrigation and fertigation events contained within the root zone, saving water and reducing the quantity of nitrate leaching to groundwater. By pumping nitrate rich water from the groundwater basin and using it to irrigate crops in such a way that significant quantities of applied nitrate is absorbed by the crops, in combination with recharging the basin with higher quality water supplies, the water quality can be improved through a regional pump-and-treat style of system. The projects and programs described in the BMP, or developed as part of the BMP implementation and described below, are designed to achieve this benefit.

The BMP is an adaptive management document that is revisited every 5 to 10 years for the purpose of determining if the projects and programs described within it remain the most effective way to achieve the stated goals, and to make refinements or consider new projects as needed based on the current conditions of the basin at the time. The priority programs described in the BMP include developing and putting to beneficial use supplemental water supplies to meet irrigation demand as a reliable alternative to groundwater pumping, enhancing groundwater recharge, and developing a robust water conservation program with a strong emphasis on irrigation efficiency for agriculture. The priority sources of supplemental water supply include recycled water and locally available surface water.

### 8.1 Existing Facilities

Operational facilities constructed by PVWMA include the Harkins Slough managed aquifer recharge and recovery facility, the Watsonville Area Water Recycling Facility, the Coastal Distribution System water conveyance pipeline, supplemental wells, and a connection to the City of Watsonville's water system. The Harkins Slough Facility was completed in 2002 and has recharged nearly 8,000 AF of surface water since that time (Figure 8.1). Harkins Slough Facility operations have had a significant and beneficial impact to both water quality and water supply in the aquifer it overlies. The recovery wells, which extract a portion of the water recharged by facility operations, have over 2,500 AF of supplemental supply for irrigation use in lieu of groundwater pumping.

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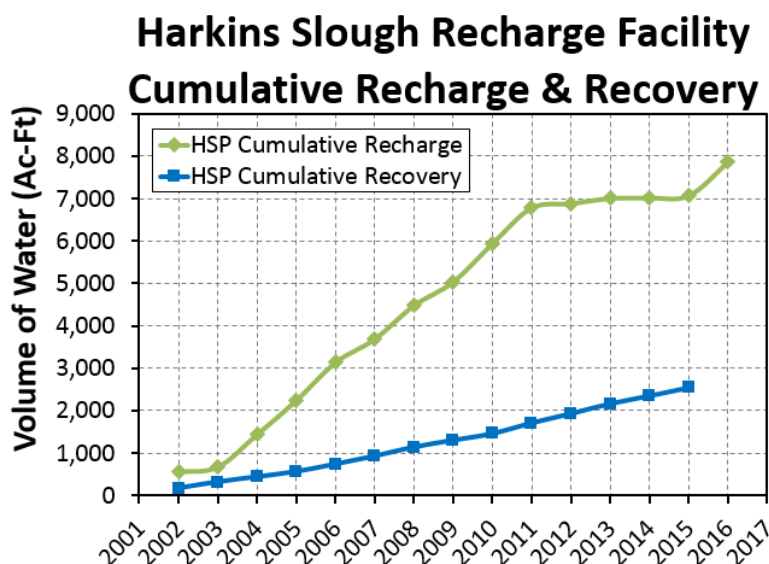


**Figure 8.1:** Harkins Slough Facility Operations with recharge shown through 4/28/2016, and recovery shown through 12/31/2015.

Recycled water use is a priority program in the BMP and a SNMP objective. The Watsonville Area Water Recycling Facility has produced over 16,200 AF of disinfected, tertiary treated, Title 22 compliant recycled water since operations commenced in 2009. As noted on Figure 6.1, recycled water use has been increasing each year and is projected to increase to 4,000 AFY by 2020. To optimize the use of recycled water, PVMWA began construction on a 1.5 MG storage tank in April 2016 to augment the existing 1.0 MG of recycled water storage. This additional storage will allow operators to treat and store night-time flows to the Waste Water Treatment Plant and deliver it to growers during the day, resulting in a projected delivery of an additional 750 AF of recycled water per year. To further improve the distribution system reliability and overall water quality while reducing reliance on the City of Watsonville's potable water supply, a Blend Well Pipeline Improvement project was constructed in 2015. This project allows the Agency to supply water from its supplemental wells directly to the main 42-inch diameter recycled water distribution pipeline through a new 2,800 linear foot pipeline. In spring 2016, the Agency constructed the K1 pipeline, a 6,800 extension to the CDS that will serve an area consisting of 180 acres of prime farmland overlying a portion of the basin heavily impacted by seawater intrusion. Operation of these facilities support the BMP by providing a supplemental supply of irrigation water for use in lieu of groundwater pumping. The long-term effect is that average groundwater production in the delivered water zone is declining through time as growers transition to supplemental water supplies (Figure 8.2).

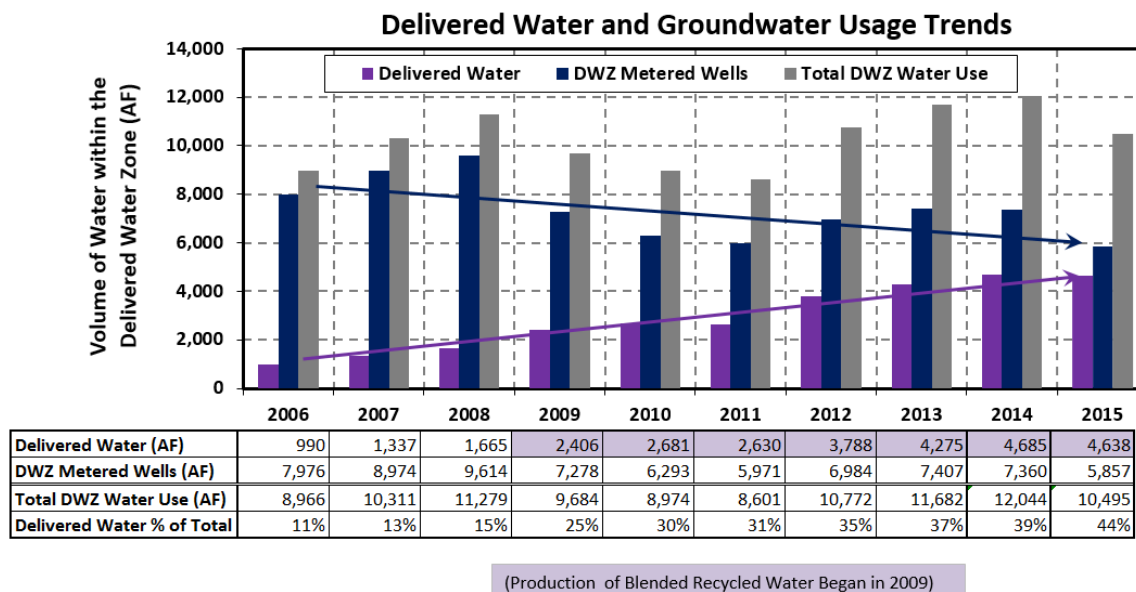


**Figure 8.2:** Delivered water and groundwater usage trends in the delivered water zone (2006 through 2015).

Following the completion and operation of several key components from the [Revised BMP \(2002\)](#), including the facilities described above, PVWMA set out to identify the next phase of projects and programs needed to solve the water resource issues of the basin. To support this effort, PVWMA collaborated with the U. S. Geological Survey to develop the [Pajaro Valley Hydrologic Model](#) (PVHM), an integrated hydrologic flow model using MODFLOW with the Farm Process that fully couples the simulation of the use and movement of water throughout the hydrologic system. After calibration and approval from a technical advisory committee, we used the PVHM to simulate the average shortfall in the groundwater budget (~12,100 AFY) for the 30 year period 1976 through 2006. In 2010 the Board of Directors formed an Ad Hoc BMP Committee that was composed of 21 voting members representing a diverse group of stakeholders. The Committee, charged with determining a suite of projects and programs to balance the basin and stop seawater intrusion, identified 44 potential solutions. We used the PVHM to evaluate the effectiveness of the proposed solutions toward attaining the stated goals. The work of the Committee culminated with a recommendation of seven projects and programs to the Board of Directors for inclusion in the [BMP Update](#) in 2012.

The BMP Update, which was adopted by the PVWMA Board of Directors in 2014, immediately following the certification of the BMP Environmental Impact Report, provides the adaptive management approach to managing the groundwater resources of the Pajaro Valley. Key components of the updated plan are listed in Table 8-1 and include: water conservation (5,000 AFY), optimizing the use of existing water supply facilities (3,000 AFY), and developing new water supply facilities (4,100 AFY). Together, the projects and programs account for the long-term offset in the water budget of 12,100 AFY. Projects are to be implemented in phases, with Phase I spanning the period 2015 to 2025. If basin monitoring activities show continued overdraft and/or seawater intrusion following the completion of each phase, additional projects that are identified and described in the BMP Update will be considered for implementation (Table 8.2). Details about each of these projects and programs are available in Chapters 4 & 5 of the [BMP](#).

**Table 8.1:** Recommended BMP Projects and Programs

| ID    | Project                                           | Yield,<br>afy | Annualized<br>Costs/Yield \$/af |
|-------|---------------------------------------------------|---------------|---------------------------------|
| D-6   | Increased Recycled Water Demand                   | 1,250         |                                 |
| S-22  | Harkins Slough Recharge Project Upgrades          | 1,000         | \$100                           |
| D-7   | Conservation                                      | 5,000         | \$200                           |
| R-6   | Increased Recycled Water Storage                  | 750           | \$700                           |
| S-2   | Watsonville Slough and North Dunes Recharge Basin | 1,200         | \$800                           |
| S-3   | College Lake with Inland Pipeline to CDS          | 2,400         | \$1,000                         |
| S-1*  | Murphy Crossing with Recharge Basins              | 500           | \$1,300                         |
| Total |                                                   | <b>12,100</b> |                                 |

\*Construction of S-1 is Phase II project.

**Table 8.2:** Potential Additional Longer-Term Projects

| ID    | Project                                                                                                      | Yield, afy | Annualized<br>Costs/Yield<br>\$/af |
|-------|--------------------------------------------------------------------------------------------------------------|------------|------------------------------------|
| I-1   | CDS expansion                                                                                                |            |                                    |
| R-11  | Winter Recycled Water Deep Aquifer ASR                                                                       | 3,200      | \$1,500                            |
| S-11  | River Conveyance of Water for Recharge at Murphy Crossing                                                    | 2,000      | \$1,500                            |
| G-3   | San Benito County Groundwater Demineralization at<br>Watsonville WWTP                                        | 3,000      | \$2,500                            |
| S-4   | Expanded College Lake, Pinto Lake, Corralitos Creek,<br>Watsonville Slough, and Aquifer Storage and Recovery | 2,000      | \$2,900                            |
| SEA-1 | Seawater Desalination                                                                                        | 7,500      | \$3,400                            |
| S-5   | Bolsa de San Cayetano with Pajaro River Diversion                                                            | 3,500      | \$3,500                            |

## 8.2 BMP Conservation Program

In the time since the BMP Update was adopted in 2014, several additional programs have been considered by the board of directors, or have been further developed by staff as in the case of water conservation. These programs, which include new approaches to incentivizing manage aquifer recharge and land fallowing, along with a more developed conservation program are summarized below.

Much work has been done to further the BMP Conservation Program since the BMP was adopted in 2014. The voluntary program provides technical and financial assistance to participating growers over the course of multiple growing seasons to maximize grower adoption of more efficient water management practices. The BMP Conservation Program also includes grower workshops and trainings, and a high-level of engagement with local partners and stakeholders to define roles, streamline activities, and leverage resources in order to maximize basin-wide progress toward conservation goals. Recent activities are summarized below.

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### 8.2.1 PARTNER COORDINATION AND LEVERAGING OF RESOURCES

One objective of the BMP Conservation Program has been to facilitate the coordination of conservation related activities being conducted by partner agencies such as the Resource Conservation Districts, the Natural Resources Conservation Service (NRCS), the U.C. Ag Extension, and other local groups to collectively achieve conservation goals in an efficient manner. Implementation of the Program has successfully increased the level of coordination among multiple partners who share an interest in achieving BMP Conservation goals, and who are helping to leverage and acquire additional resources to achieve these goals. Below are examples of recent accomplishments.

- PVWMA was awarded an IRWM Drought Response grant in partnership with the RCD-SCC in 2015. Approximately \$256,000 in grant funds are currently being used to expand the PVWMA's Drought Response Irrigation efficiency Program, or DRIP. In addition, some of the money is being used by the RCD-SCC to fund a nutrient and irrigation technical expert. This position is partnering with existing technical service providers to meet the needs of growers as the PVWMA's Irrigation Efficiency Program expands, and as new programs come online.
  - The RCD-SCC and the Community Water Dialogue continue to support progress toward BMP Conservation goals by bringing additional resources in the form of grant funds to the Pajaro Valley. Examples of new programs include an IRWM grant led by RCD-SCC to implement two small-scale managed aquifer recharge projects, an NRCS grant co-sponsored by the RCD-SCC and Community Water Dialogue to provide irrigation and nutrient management services to growers, and an IRWM grant managed by RCD-SCC to implement a mobile irrigation lab. The mobile lab is being coordinated with the PVWMA's Irrigation Efficiency Program.
  - PVWMA supported the expansion of the Community Water Dialogue-led Wireless Irrigation Network Loaner Program by doubling the number of loaner sets from four to eight. This program provides equipment and technical assistance that allows growers to "see" their irrigation events infiltrate into the ground and allows them to be better informed with respect to scheduling irrigation and fertilizer events. Because the equipment measures soil moisture tension at two or more elevations within the soil column, a grower or their irrigator will know when the irrigation event has reached desired root depths. This information is being used to help keep fertilizer in the root zone, reducing the leaching of nutrients to groundwater.
  - The PVWMA board of directors, in collaboration with growers is planning a voluntary, land fallowing incentive pilot program in the Pajaro Valley. While the details of this program are still in development, \$200,000 is allocated for the 2016/17 fiscal year budget. Fallowing land within the PVGB will ease demand from groundwater while facilitating the more efficient recharge of rain water, and may have a beneficial impact on soil quality.
  - PVWMA is sponsoring a series of water conservation technical workshops to provide information on the tools available to assist growers. Workshops are held both in meeting rooms and in "tailgate" forms in the field, and they address a broad range of topics including the irrigation scheduling tool CropManage, monitoring irrigating system pressure to improve distribution uniformity, the use of wireless soil moisture sensors, and more. To support adoption of new techniques, PVWMA offers growers rebates for equipment purchases that lead to more efficient water use.
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- As part of the BMP Conservation Program, PVWMA launched a Water Awareness media campaign in the fall 2014 and has continued funding it. Multi-media messaging on TV, radio, and web-based outlets are an important part of this program.

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### 8.2.2 RECHARGE NET METERING PILOT PROGRAM

In March 2016, the board of directors approved a 5-year Recharge Net Metering (ReNeM) pilot program. The program, developed in collaboration with the University of California, Santa Cruz (UCSC), and the RCD-SCC, is intended to augment and support the BMP by helping to collect and recharge stormwater runoff in strategic locations within the PVGB, bringing additional diversification to existing groundwater recharge efforts. The pilot ReNeM program is consistent with stated BMP goals focused on eliminating groundwater overdraft and halting seawater intrusion. In a time when long-term drought is a real threat, and precipitation patterns appear to be changing to shorter duration, more intense rain events, this proposal has the potential to diversify and make more adaptable the valley's managed aquifer recharge portfolio by routing a small fraction of stormwater runoff into aquifers. The program provides a financial incentive to landowners to develop recharge basins in locations that are connected the aquifer. The incentive comes in the form of a rebate based on every acre-foot of enhanced recharge resulting from the project, where enhanced recharge means in addition to incidental recharge that may have been occurring due to existing conditions. The goal of the pilot program is to recharge 1,000 AFY through 8-10 projects. In addition to providing supply to the basin, the high quality of stormwater runoff will improve groundwater quality. This amount of recharge and effect on water quality will be measured by UCSC researchers. Projects will use a mixture of technologies (infiltration basins, dry wells, reactive barriers to improve water quality, etc.), with each system being designed individually based on local needs and limitations. Projects will be selected and designed so as to minimize flooding, clogging, or other problems. All projects will be fully permitted, with the RCD-SCC providing leadership in this area.

The priority projects and programs described above support the BMP goals of stopping groundwater overdraft and halting seawater intrusion. Optimizing the production, delivery, and use of supplemental water supplies directly offsets groundwater production in the coastal area where seawater intrusion is most severe. Recharge facilities enhance supply and improve groundwater quality. Conservation programs help to reduce water use. Collectively these programs have a beneficial impact on both groundwater quality and supply.

## 8.3 Projection of Seawater Intrusion and Groundwater Levels

The PVHM simulations indicate that that use of supplemental water supplies in lieu of groundwater production within the 7,600 acre Delivered Water Zone (DWZ) is expected to significantly reduce the rate of seawater intrusion. The [Hydrologic Model Analysis of Basin Management Plan Alternatives](#) (PVWMA, 2013) provides a comparison of baseline and selected alternative simulations with respect to seawater intrusion and overdraft into the Alluvial Aquifer, the Upper Aromas Aquifer, and the lower Aromas Aquifer. A baseline simulation (not including selected BMP projects and programs) shows that seawater intrusion into the three aquifers total 1,900 AFY, and there is 1,400 AFY in overdraft. Model results from the selected alternative simulation indicate that seawater intrusion into the Alluvial Aquifer, Aromas Aquifer, and Lower Aromas Aquifer will continue at 200 AFY, representing a 90% reduction in seawater intrusion. Most of the remaining seawater intrusion is projected to occur in the Lower Aromas Formation. Average groundwater elevations are also expected to rise within each of the

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three aquifers of concern, with the largest rises in areas near the DWZ. An example of reductions in seawater intrusion into the Aromas Aquifer is shown in Figure 8.3. The [Hydrologic Model Analysis of Basin Management Plan Alternatives](#) provides additional examples and results for the other PVGB aquifers of interest as well as maps showing projected overdraft in Section 6 (PVWMA, 2013).

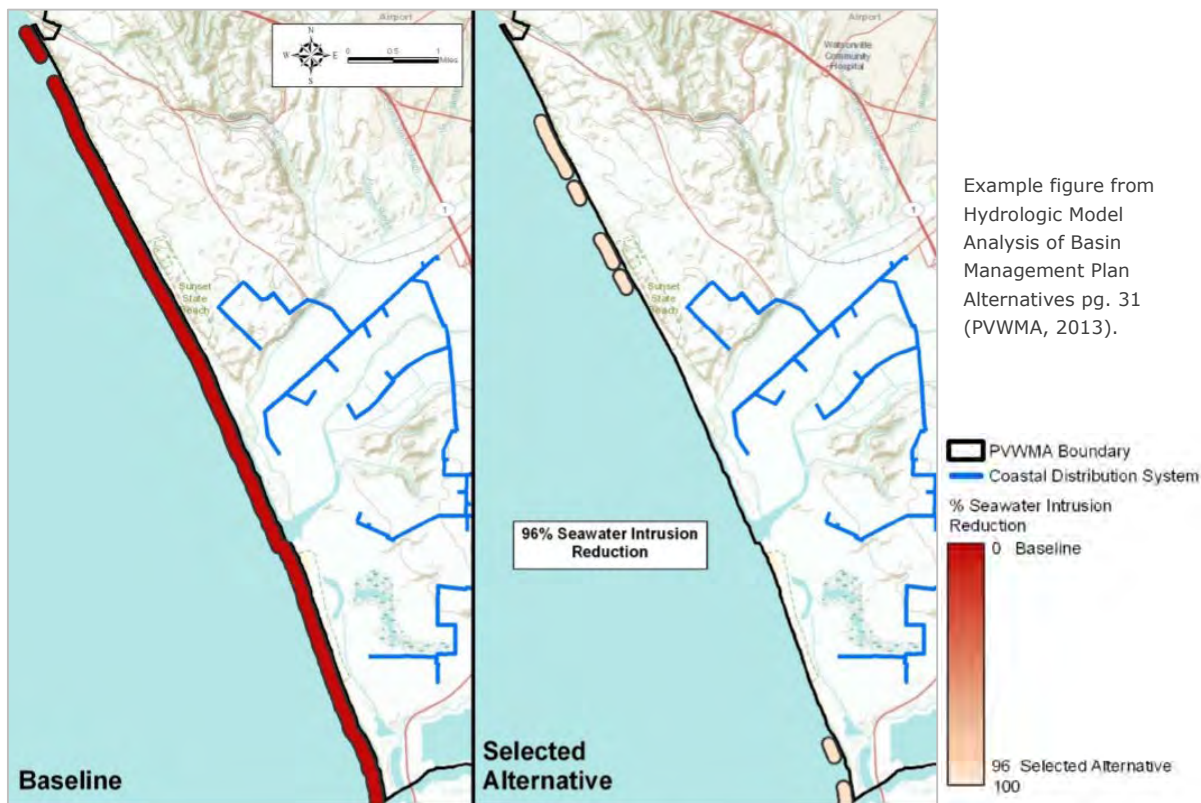


**Figure 8.3:** Example results comparing baseline and selected alternative simulation for Upper Aromas Aquifer. White and clear areas indicate increased reduction in seawater intrusion (PVWMA, 2013).

## 9 MONITORING PLAN

Monitoring the quantity and quality of water within the Pajaro Valley is an important aspect of achieving the Agency's mission to efficiently and economically manage existing and supplemental water supplies in order to prevent further increase in, and to accomplish continuing reduction of, long-term overdraft. The Agency has developed, and continues to refine monitoring programs that guide data collection efforts important to understanding both the state of the Pajaro Valley Groundwater Basin and the effect of Agency's water supply facilities on the basin. Agency staff routinely monitor groundwater, surface water, supplemental water (i.e. recycled water and water recovered from managed aquifer recharge), soils, land use, weather and climate. Data from these programs are processed through quality control / quality assurance procedures before being stored and maintained in Agency databases, which include geo-databases that allow for the data to be viewed spatially. The purpose of these programs is to track changes and monitor trends in order to accurately inform staff, the board of directors, and stakeholders about the state of the basin. A more detailed description of each program is provided below.

### 9.1 Groundwater Monitoring Program

The groundwater monitoring program is designed to measure changes in storage and quality within the PVGB through the collection and analysis of metered groundwater extractions, levels, and quality. The program consists of several distinct networks, each with specific purposes. Data collected from this program enable staff to track the effects of groundwater extraction and water resource management activities, which include facility operations and conservation programs, on the Basin.

Groundwater extraction facilities (wells) equipped with flow meters allow for the accurate measurement of the volume of water produced from the PVGB. Staff collect groundwater extraction data quarterly from 863 production wells. Each well is equipped with flow a meter that measures the total volume of water produced by the well and provides information about flow rates. Staff follow a meter maintenance program that includes routine accuracy tests to check that meters are working properly. Meter calibrations are conducted regularly by trained staff to verify accuracy. Production from smaller, unmetered rural residential wells is estimated based on a study of two local water districts, and one water mutual services company: Aromas Water District, Central Water District, and the San Andreas Water Mutual Company (PVWMA Service Charge Report, January 2015).

Groundwater levels and water quality samples are currently collected from over 170 wells, both publicly and privately owned, each year. Over the past decade more than 300 unique wells have been monitored, a majority of which are privately owned. The Agency has been working to install more publicly owned, dedicated monitoring wells in strategic locations to increase both the availability and reliability of these valuable data collection points.

The Agency's largest groundwater level and quality data collection effort occurs semi-annually, during which time staff visit approximately 170 wells distributed throughout the PVWMA service area (Figure 2.1). Some of the wells included in this network were monitored by the counties of Monterey and Santa Cruz prior to the formation of the Agency in 1984, and have rich, historical records that date back as far as the 1940s. Monitoring activities are conducted in the spring and the fall during times when groundwater surface elevations are anticipated to be at the highest and lowest levels, respectively. During each monitoring effort staff visit each well in the network two or more times in an

attempt to obtain both 1) a static water level measurement when the well is off, and 2) a water sample for quality analyses when the well is in operation. A list of the water quality constituents analyzed under the PVWMA groundwater monitoring program is provided in Table 9.1.

In an effort to track seasonal variations to groundwater levels throughout the valley, staff monitor a subset of the semi-annual wells on a monthly frequency, or greater, in the case of the Agency constructed, publicly owned “PV Wells.” This “monthly monitoring network” currently consists of 48 wells and is composed of a combination of public and privately owned wells. The “PV Wells” are dedicated monitoring wells that were first constructed in 1988, proximate to the coast, to provide controlled sampling locations in order to investigate the extent seawater intrusion. Additional PV Wells have since been constructed at locations further inland to fill known data gaps. The PV Wells are instrumented with autonomous pressure transducers that record water level measurements on a specified frequency (often every 15 or 60 minutes), and low flow pumps that allow staff to efficiently collect water quality samples from targeted elevations within the aquifer. The groundwater level data from the monthly monitoring network provides staff with the resolution needed to observe groundwater level fluctuations in the basin that are not captured in semi-annual monitoring, and help inform timing of semi-annual monitoring events each year.

In addition to the groundwater monitoring efforts described above, the Agency monitors 27 wells associated with the Harkins Slough Managed Aquifer Recharge & Recovery Facility. Of the wells proximate to the recharge basin, 16 are dedicated monitoring wells, and 11 are recovery (production) wells. Nearly all of these wells are equipped with autonomous pressure transducers to track water levels and pumps to obtain samples for water quality analyses. Data collected from the 27 Harkins Slough wells serves to inform staff of changing groundwater conditions resulting from facility operations and enables more effective operation of the facility.

Data collected from the groundwater monitoring program are used for a variety of purposes that inform basin management activities. For example, groundwater surface elevation maps are produced annually using water level results. Water level data have also been used extensively in the development of the PVHM, from serving as calibration points to checking the accuracy of predicted water levels. Maps and tables describing groundwater quality conditions are produced annually and as needed. The data also are used to support other hydrologic studies, including those looking into groundwater – surface water interactions, and the development of environmental impact reports. Products generated from the data are regularly presented during stakeholder meetings intended to help keep the public aware of the current conditions within their groundwater basin.

## 9.2 Surface Water Monitoring Program

Surface water provides a significant source of recharge supply to the PVGB and has the ability to be harnessed for other beneficial uses such as augmenting supplemental supplies. The surface water monitoring program has been designed to track fluctuations of water quality and water levels in both streams and water bodies. When used in conjunction with a calibrated stage-discharge curve, water levels in streams provide useful information about streamflow. In the case of water bodies such as College Lake, the water level data can be used with a stage-capacity curve to indicate the volume of water in storage. The USGS maintains gauges on the Pajaro River at Chittenden Gap (USGS Station ID 11159000), and Corralitos Creek at Green Valley (USGS Station ID 11159200). While a surface water monitoring program is important for many reasons, one of the fundamental reasons is to better understand the quality of surface water recharging the groundwater basin and how it may be changing in time.

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The surface water monitoring program is dynamic and has grown to meet the needs of existing facilities and proposed projects. The Agency initiated the program in 1994 and at that time it contained 10 monitoring sites that provided water quality data on the Pajaro River, Corralitos Creek, Harkins Slough, College Lake, and associated tributaries. The majority of surface water quality monitoring conducted between the years of 1994-2003 focused heavily on the rainy season months of November through May with limited sampling during the drier months of the year. By 2004, the network had grown to a total of 21 monitoring sites by increasing the number of sites sampled on important streams and tributaries, and by adding new streams to the network. Monthly sampling also commenced at that time.

The surface water monitoring program has evolved over the past decade, with staff continuing to monitor the original core sites and additional sites as needed for discrete watershed specific studies as noted below. In 2015, the surface water monitoring network consisted of 30 monitoring sites tracking water quality and/or stage of 21 water bodies within the Pajaro Valley (Figure 4.10). Staff maintain autonomous logging instruments that collect 30-minute interval temperature, depth, and in some cases salinity data at 22 key surface water sites. When the streams are flowing, samples are collected and analyzed for a suite of major anions and cations (see Table 9.1 for a list of analytes). The frequency of surface water network monitoring has varied over the years from monthly to quarterly time scales, and is currently conducted bi-monthly.

Data collected from the surface water monitoring network serves numerous beneficial purposes. Monitoring the quality of surface water, and how it changes with time, provides an indication of how the quality of groundwater may change with time as a result of recharge processes within the different regions of the Pajaro Valley. Data collected from this program supports the development of both programmatic and project specific environmental impact report needs, and other planning documents such as this Salt and Nutrient Management Plan. Data are integral to the building of regional and localized hydrologic and hydraulic models. A recent example of how the data support a regional scale model is the Pajaro Valley Hydrologic Model (PVHM), which is summarized in Chapter 3 and described in detail in Hanson *et al.* (2014). On the sub-watershed scale, hydrologic and hydraulic models were recently developed for the College Lake (RCD-SCC, 2014a) and Watsonville Slough System watersheds (RCD-SCC, 2014b). In these cases, the models simulate the use and movement of surface water, including flood flows, through the watersheds. Lastly, the data are used to meet permitting needs such as those imposed by the Central Coast Regional Water Quality Control Board for the Harkins Slough Facility diversion. In this case, the Agency operates under a NPDES low threat discharge permit.

### 9.3 Supplemental Water Monitoring Program

The supplemental water monitoring program was developed to monitor water quality, production, and use of the Agency's supplemental water supply facilities. The program consists of two primary components, source-water supply and endpoint use monitoring. Staff monitor the individual source-water supply facilities that provide water to the Coastal Distribution System (CDS), which is the pipeline that moves water from the facilities where it is produced to the growers who apply it to their crops in-lieu of pumping groundwater. Presently four source water-water supply facilities exist, including: 1) the Recycled Water Facility, 2) the Harkins Slough Managed Aquifer Recharge and Recovery (MAR) Facility, 3) the Blend Water Supply Wells, and 4) the City of Watsonville's potable supply. In addition to the samples staff collect at the Recycled Water Facility, the Agency has retained

the Monterey County Department of Health Services, as an independent third party to test the disinfected, tertiary treated water for clostridium and coliforms, including e-coli, twice per month.

The second component of the program is focused on monitoring of the endpoint delivered water quality and volume, and is measured at each active turnout of the CDS. Turnouts along the CDS are sampled biweekly to track fluctuations in water quality. During the primary growing season from April to September, staff typically collected twenty samples from active turnouts spatially distributed throughout the CDS along with source samples on a monthly frequency. In the months with lower demand, turnout samples are collected less frequently.

The monitoring program and sampling schedule for water supply facilities is reviewed and set by the Projects and Facility Operations Committee (the Committee). This committee is composed of agency directors, growers, County Environmental Health representatives, the public at-large, and staff. Tables 9.1 and 9.2 list the locations sampled and constituents analyzed for each of the source water facilities listed above on a monthly basis. Knowing the quality of the water produced by each facility, and how it fluctuates throughout the year helps water system operators meet quality objectives established by the Project and Facility Operations Committee. The goals are to maintain chloride at less than 150 mg/L, sodium at less than 100 mg/L, and sodium adsorption ration (SAR) at less than 4, by adjusting blend ratios appropriately.

In early 2014, following five-years of rigorous monitoring since recycled water deliveries commenced, staff conducted a thorough review of the supplemental water monitoring program to identify potential gaps, redundancies, and possible analytical service cost savings. Results of this effort were presented to the Committee for discussion and direction. In July 2014, a more dynamic sampling program was implemented to target sampling of all active delivery points along the CDS at least once per year while maintaining monthly source sampling (Figure 4-14).

Other facility specific monitoring includes that which is required by permit. The Harkins Slough Facility has monitoring requirements as part of a National Pollutant Discharge Elimination System (NPDES) Low Threat Discharge permit. The Recycled Water Facility likewise has monitoring requirements as part of the Master Reclamation Permit (MRP) for the production and distribution of recycled water. The MRP describes in detail sampling requirements for Title 22 compliance. The NPDES and MRP permits are available from the Agency upon request. With regard to constituents of emerging concern (CECs), the Recycled Water Policy Attachment A states that monitoring health-based CECs or performance indicator CECs is not required for recycled water used for landscape irrigation due to the low risk of ingestion of the water and thus they are not included in the sampling program.

## 9.4 Soil Monitoring Program

The Agency developed a soil monitoring program in 2005, four years prior to deliveries of recycled water, in order to establish baseline soil quality. The baseline data would provide a point of comparison for potential changes in soil chemistry following the delivery of blended, recycled water. The program initially consisted of three monitoring sites with similar soil characteristics: one site inside the Delivered Water Zone (DWZ) and within the area impacted by seawater intrusion; one site inside the DWZ but outside the area impacted by seawater intrusion; and a control site located outside of the both the DWZ and area impacted by seawater intrusion.

By 2010, three additional sites were incorporated into the monitoring program, bringing the total current number of sites to six. At present, staff collect samples at each site three times per year:

March, at the beginning of the growing season; August, in the middle of the growing season; and November, at the end of the growing season. Soil samples are collected at one-foot intervals to a depth of three feet below the ground surface, and are analyzed for mineral and chemical composition (see Table 9.1 for list of analytes). Field notes and a picture catalog detailing site conditions and any irregular circumstances at the time of sample collection are maintained. Data from this monitoring program are summarized annually, presented at grower meetings and the Projects and Facility Operations Committee, and published in the MRP annual report.

## 9.5 Land Use Monitoring Program

The Agency initiated a land use monitoring program in 2009 in order to gain a better understanding of cropping patterns, including land fallowing. Development of the PVHM demonstrated a need for more frequent land use data than was publicly available from sources such as the U.S. Department of Food and Agriculture and the CA Department of Water Resources. While this program takes into account all of the land uses within the PVGB, the focus is on mapping agricultural land use in order to better understand changing crop trends and the associated water demands that accompany each crop. The primary crops grown in the Pajaro Valley have changed over recent years. Apple orchards, which demand a relatively modest amount of water, have been replaced with higher value, greater water demand crops such as strawberries and caneberries.

Land use surveys have been conducted at an annual frequency or greater since 2011. Historically, land use surveys have been conducted in the summer during the peak of the growing season to document fluxes in land use as well as longer trends across the Pajaro Valley. More recently, due to an interest in learning more about valley-wide cover cropping activities, staff have undertaken a winter land use surveying effort.

The applications of the land use data are numerous. For instance, land use data is an important input to the PVHM, which simulates water demand based on crop type and weather among other factors. Additionally, the data enable staff to document land use trends, many of which have impacts on water and fertilizer demand. The 2011/2012 land use mapping efforts were used to determine agricultural crop distribution displayed in Figure 5.16.

## 9.6 Weather and Climate Monitoring

The California Irrigation Management Information System (CIMIS) is a program unit in the Water Use and Efficiency Branch, Division of Statewide Integrated Water Management, California Department of Water Resources (DWR) that manages a network of over 145 automated weather stations in California (<http://www.cimis.water.ca.gov/>). CIMIS was developed in 1982 by DWR and the University of California, Davis (UC Davis). It was designed to assist irrigators in managing their water resources more efficiently. Three CIMIS stations exist within the PVGB. These include the Watsonville West II, Green Valley, and Pajaro stations. The Agency hosts and maintains the Watsonville West II station. Each CIMIS site records weather data that is publically accessible and can be queried in hourly, daily, and monthly intervals. These stations provide Pajaro Valley growers with a reference evapotranspiration rate (ET<sub>o</sub>) that may be used to assist with irrigation scheduling and efficiency. The rainfall and ET<sub>o</sub> data are utilized PVWMA in the development and updates of hydrologic models and measuring stresses to crop water demand.

## **9.7 Responsible Party, Sampling Protocols, Quality Assurance, and Quality Control**

The Agency's staff are responsible for collecting, compiling, conducting quality assurance / quality control (QA/QC), and reporting results of the data obtained via the programs described above. Samples are collected by water resource professionals trained in best practices. Field data are recorded in field books or worksheets and are accompanied by photo documentation when appropriate. Proper sample collection and handling is important to obtaining accurate and reliable results. Samples collected for water quality analyses are correctly labeled, transported in coolers packed with ice, and tracked using chain-of-custody forms. All samples are sent to California State Certified Environmental Laboratories (ELAP) with implemented analytical QA/QC programs, which include procedures to reduce variability and errors, identify and correct measurement problems and provide a statistical measure of data quality.

Storage of large volumes of data with the ability to search and return queries is an important part of the Agency's monitoring programs. Databases have been built to specifically track the types of data collected by the Agency. The databases have been designed with built-in controls and primary keys that are used to protect the integrity of the data. For example, unless a site exists within a master site table, or a constituent exists within a constituent table, the database will not allow that record to be saved. Functionality has been built into the database to allow the direct input of digital results received from the laboratory, thereby reducing the potential for data entry error. The Agency's primary laboratory worked directly with the Agency to develop a data output system to make this functionality work. For official purposes, results are sent from the laboratory in the form of stamped PDF reports. As an additional measure of redundancy, the laboratory keeps both a portion of unused samples in case they need to be run again to validate a result, and copies of all records. Prior to any data being imported into the databases, staff perform a visual inspection of the data and run the data through spreadsheet based tools designed to assist with QA/QC as appropriate.

## **9.8 Salt and Nutrient Monitoring Program**

The Agency will continue the comprehensive monitoring programs described above which includes the collection of data pertaining to salt and nutrient management. The monitoring programs will expand and evolve through time to address any identified shortfalls or data gaps to meet Agency needs for water resource management planning activities and facility operations in working toward the goal of sustainable groundwater management.

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Table 9.1: PVWMA monitoring program analytes.

| Analyte                                         | Groundwater | Surface Water | Supplemental Water | Soils |
|-------------------------------------------------|-------------|---------------|--------------------|-------|
| Ammonia                                         |             |               | ✓                  | ✓     |
| Alkalinity, Total (as CaCO <sub>3</sub> )       | ✓           | ✓             | ✓                  |       |
| Bicarbonate (as HCO <sub>3</sub> <sup>-</sup> ) | ✓           | ✓             | ✓                  |       |
| Boron                                           | ✓           | ✓             | ✓                  | ✓     |
| Bromide                                         | ✓           | ✓             | ✓                  |       |
| Calcium                                         | ✓           | ✓             | ✓                  | ✓     |
| Carbonate as CaCO <sub>3</sub>                  | ✓           | ✓             | ✓                  |       |
| Cation Exchange Capacity (CEC)                  |             |               |                    | ✓     |
| Chloride                                        | ✓           | ✓             | ✓                  | ✓     |
| Copper                                          |             |               |                    | ✓     |
| Electrical Conductivity (ECE)                   |             |               |                    | ✓     |
| Fluoride                                        | ✓           | ✓             | ✓                  |       |
| Hardness (as CaCO <sub>3</sub> )                | ✓           | ✓             | ✓                  |       |
| Iron                                            |             |               |                    | ✓     |
| Kjeldahl Nitrogen                               | ✓           | ✓             | ✓                  |       |
| Langlier Index (60 deg. C)                      | ✓           | ✓             | ✓                  |       |
| Magnesium                                       | ✓           | ✓             | ✓                  | ✓     |
| Manganese                                       |             |               |                    | ✓     |
| Nitrate as NO <sub>3</sub>                      | ✓           | ✓             | ✓                  |       |
| Nitrate as NO <sub>3</sub> -N                   | ✓           | ✓             | ✓                  | ✓     |
| Nitrite as NO <sub>2</sub> -N                   | ✓           | ✓             | ✓                  |       |
| o-Phosphate-P                                   | ✓           | ✓             | ✓                  |       |
| Organic Matter %                                |             |               |                    | ✓     |
| pH (Laboratory)                                 | ✓           | ✓             | ✓                  | ✓     |
| Phosphorous                                     |             |               |                    | ✓     |
| Potassium                                       | ✓           | ✓             | ✓                  | ✓     |
| SAR (Sodium Adsorption Ratio)                   | ✓           | ✓             | ✓                  | ✓     |
| SAR, Adjusted                                   | ✓           | ✓             | ✓                  |       |
| Settleable Solids                               |             | ✓             | ✓                  |       |
| Sodium                                          | ✓           | ✓             | ✓                  | ✓     |
| Specific Conductance (E.C.)                     | ✓           | ✓             | ✓                  |       |
| Sulfate                                         | ✓           | ✓             | ✓                  | ✓     |
| Total Diss. Solids                              | ✓           | ✓             | ✓                  |       |
| Total Nitrogen                                  | ✓           | ✓             | ✓                  | ✓     |
| Total Susp. Solids                              |             | ✓             | ✓                  |       |
| Turbidity                                       |             | ✓             | ✓                  |       |
| Zinc                                            |             |               |                    | ✓     |

Table 9.2: Monitoring Program Summary

| Monitoring Program & Network      | # of Sites | Start Date of Longest Active Site | Start Date of Shortest Active Site | Average Length of Time Monitored |
|-----------------------------------|------------|-----------------------------------|------------------------------------|----------------------------------|
| <b>Groundwater Monitoring</b>     |            |                                   |                                    |                                  |
| Semi-Annual Monitoring Wells      | 171        | 2/20/1947                         | 11/5/2015                          | 26 years                         |
| Monthly Monitoring Wells          | 48         | 3/5/1947                          | 11/5/2015                          | 27 years                         |
| Harkins Slough Monitoring Wells   | 16         | 1/5/1995                          | 7/25/2012                          | 9 years                          |
| Metered Production Wells          | 863        | 7/1/1996                          | 11/23/2015                         | See Note 1                       |
| <b>Surface Water</b>              |            |                                   |                                    |                                  |
| Bimonthly Surface Monitoring      | 31         | 10/21/1994                        | 2/28/2014                          | 17 years                         |
| Instrumented Surface Monitoring   | 22         | 4/20/2001                         | 12/11/2015                         | 5 years                          |
| <b>Supplemental Water</b>         |            |                                   |                                    |                                  |
| Recycled Water                    | 1          | 4/1/2009                          | 4/1/2009                           | 7 years                          |
| City of Watsonville Potable Water | 1          | 6/3/2010                          | 6/3/2010                           | 5 years                          |
| Harkins Slough Recovery Wells     | 11         | 2/6/2003                          | 7/16/2012                          | 12 years                         |
| Blend Wells                       | 2          | 11/12/2003                        | 6/3/2004                           | 12 years                         |
| CDS Turnouts                      | 86         | 3/25/2002                         | 7/3/2013                           | 7 years                          |
| <b>Soil</b>                       | 6          | 12/8/2005                         | 12/15/2010                         | 8 years                          |
| <b>Land Use</b>                   | N/A        | 6/1/2009                          | N/A                                | 8 years                          |

Notes: In 1996, the initial year meters were installed on wells, there were 432 active sites. In 2000, there were 696 metered wells and in 2010 there were 895.

## 10 ANTIDEGRADATION ANALYSIS

### 10.1 Recycled Water Irrigation Projects

The Recycled Water Policy requires that each SNMP include an antidegradation analysis that demonstrates that “projects included within the plan will, collectively, satisfy the requirements of Resolution No. 68-16”. Resolution No. 68-16 is the basis for the Antidegradation Policy and states, in part, that recycled water must be regulated with the maximum benefit to the people of the State. Any project included within the SNMP must comply with a number of elements outlined in Resolution No. 68-16 and described below in Chapter 10.3. The following sections provide a brief summary of the history of the Watsonville Area Water Recycled Water Treatment Facility along with recycled water use areas, describe regulatory requirements, and demonstrate compliance through analysis of recycled water use.

### 10.2 Recycled Water Irrigation Projects

The recycled water project within the Pajaro Valley includes the current and future use of the Watsonville Area Recycled Water Treatment Facility. The Recycled Water Facility began supplying tertiary treated, disinfected, Title 22 compliant water in 2009 to coastal ranches as a source of agricultural irrigation supply in-lieu of groundwater pumping in areas impacted and susceptible to seawater intrusion. The Delivered Water Zone (DWZ), which includes all areas capable of receiving supplemental water supplies, is over 7,600 acres in total size (Figure 4.14), and includes approximately 5,500 irrigated acres of agriculture. The delivered water is a blend of supplies from the following four sources: 1) Recycled water; 2) water from the Harkins Slough Facility Recovery Wells; 3) PVWMA Blend Wells; and 4) the City of Watsonville Potable Water Supply. The Recycled Water Facility was constructed with a capacity to produce 4,000 AFY. Projects described in the Basin Management Plan that include increasing delivered water sales and the construction of additional recycled water storage are underway in an effort to optimize the production and use of recycled water. As shown in Figure 6.1, it is projected that the Agency will deliver 4,000 AFY of recycled water in addition to blend supplies by 2020. No other recycled water projects are being planned for the Pajaro Valley at this time.

### 10.3 SWRCB Recycled Water Policy Criteria

The SWRCB adopted Resolution No. 68-16 in 1968 to protect water quality. This became the foundation for the Antidegradation Policy, stating the intention that all water of the state shall be regulated to “achieve the highest water quality”. The Recycled Water Policy mandates that any project included within a SNMP complies with Resolution 68-16 and states in part:

- a) *The State Water Board adopted Resolution No. 68-16 as a policy statement to implement the Legislature’s intent that waters of the state shall be regulated to achieve the highest water quality consistent with the maximum benefit to the people of the state.*
  - b) *Activities involving the disposal of waste that could impact high quality waters are required to implement best practicable treatment or control of the discharge necessary to ensure that pollution or nuisance will not occur, and the highest water quality consistent with the maximum benefit to the people of the state will be maintained.*
-

d) *Landscape irrigation with recycled water in accordance with this Policy is to the benefit of the people of the State of California. Nonetheless, the State Water Board finds that the use of water for irrigation may, regardless of its source, collectively affect groundwater quality over time. The State Water Board intends to address these impacts in part through the development of salt/nutrient management plans.*

- (1) *A project that meets the criteria for a streamlined irrigation permit and is within a basin where a salt/nutrient management plan satisfying the provisions of paragraph 6(b) is in place may be approved without further anti-degradation analysis, provided that the project is consistent with that plan.*
- (2) *A project that meets the criteria for a streamlined irrigation permit and is within a basin where a salt/nutrient management plan satisfying the provisions of paragraph 6(b) is being prepared may be approved by the Regional Water Board by demonstrating through a salt/nutrient mass balance or similar analysis that the project uses less than 10 percent of the available assimilative capacity as estimated by the project proponent in a basin/sub-basin (or multiple projects using less than 20 percent of the available assimilative capacity as estimated by the project proponent in a basin/sub-basin).*

## 10.4 Antidegradation Assessment

The CCRWQCB has recommended that SNMPs demonstrate that SNMP-related projects protect beneficial uses on both a localized and regional scale, and that assimilative capacity may be evaluated for distinct subareas or management areas (CCRWQCB, 2014). In the case of the Watsonville Recycled Water Treatment Facility, the project has already been implemented and the impact to groundwater quality assimilative capacity can be directly evaluated for management areas (the DWZ) and at regional scales (Zone 2). Delivered water from the Watsonville Recycled Water Treatment Facility is a mix of multiple sources. Recycled water is blended with water pumped from PVWMA and City of Watsonville wells to reduce the salinity. The concentrations of the blended water are monitored at turnouts within the Coastal Distribution System. A total of 563 samples were taken from the delivered water supply between April 2009 and April 2015. The delivered water quality was compared to the existing groundwater quality in the DWZ (Figure 4.14), for the coastal area (Zone 2), and to the assimilative capacity WQOs for the Pajaro Valley (Table 10.1).

**Table 10.1:** Comparison of delivered water quality to the existing groundwater conditions within the DWZ, the coastal area (Zone 2), and to the regional WQOs.

| Constituent             | Delivered Water Quality (mg/L) | DWZ* Avg Existing Groundwater Conditions (mg/L) | Zone 2 (coastal)** Existing Groundwater Conditions (mg/L) | Water Quality Objectives (mg/L) |
|-------------------------|--------------------------------|-------------------------------------------------|-----------------------------------------------------------|---------------------------------|
| TDS                     | 612                            | 756                                             | 730                                                       | 1000                            |
| Chloride                | 104                            | 190                                             | 198                                                       | 150                             |
| Nitrate NO <sub>3</sub> | 27                             | 36                                              | 39                                                        | 45                              |

\*DWZ is illustrated in Figure 4.14. \*\* Zone 2 is displayed in Figure 7.1.

Table 10.1 indicates that the delivered water contains lower concentrations for each of the constituents of interest compared to the groundwater concentrations for both the DWZ and the coastal area (Zone 2). The delivered water quality also falls beneath the assimilative capacity threshold defined by the WQOs. This simple comparison suggests that increased use of delivered water for

irrigation in conjunction with simultaneous reductions in local groundwater extraction may dilute the groundwater salt and nutrient concentrations within the area beneath the DWZ in the future. An additional benefit to the use of delivered water is the reduction of groundwater extraction, which is a primary driver of groundwater overdraft and a leading cause of seawater intrusion. Reducing the rates of seawater intrusion has a myriad of water quality benefits, is critical to maintaining beneficial uses of water (Chapter 5.1.1; Seawater Intrusion), and is a primary objective of the Basin Management Plan.

In addition to verification that assimilative capacity thresholds have not been exceeded, a project must demonstrate compliance with Resolution 68-16. Table 10.2 lays out each component of Resolution 68-16, and describes how the project meets stated requirements. The use of recycled water produced by the Watsonville Recycled Water Treatment Facility is consistent with the goals outlined in the Recycled Water Policy, helping California “move towards sustainable management of surface waters and groundwater”.

**Table 10.2** Table listing how recycled water project complies with each element of Resolution No. 68-16

| SWRCB Resolution No. 68-16 Component                                                                                                        | Antidegradation Assessment                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|---------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Water quality degradation associated with recycled water project(s) will be consistent with the maximum benefit of the people of the State. | <ul style="list-style-type: none"> <li>The Watsonville Recycled Water Treatment Facility helps mitigate seawater intrusion by reducing pumping in the coastal area, reducing the rate of seawater intrusion and contributing to improved groundwater quality. The project has already been implemented. Economic and social costs and benefits are described thoroughly in PVWMA's update to the Basin Management Plan (PVWMA 2014).</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                            |
| The recycled water project(s) will not unreasonably degrade actual or potential beneficial uses.                                            | <ul style="list-style-type: none"> <li>The delivered water has lower concentrations of salts and nutrients (TDS, chloride, and nitrate) than groundwater in both the DWZ and larger subarea where the project has been completed. An increase in use of delivered water within the DWZ and concurrent reductions in the amount of local groundwater used for irrigation in this location may dilute the groundwater salt and nutrient concentrations within the area beneath delivered water zone in the future.</li> </ul>                                                                                                                                                                                                                                                                                                                |
| The recycled water project(s) is necessary to accommodate important economic or social development.                                         | <ul style="list-style-type: none"> <li>The project provides a water supply alternative for growers in coastal areas within the delivered water zone, and is a major component of the suite of projects and programs being implemented to achieve sustainable water resources in the Pajaro Valley. The delivered water supply has allowed the growers in the DWZ to maintain production of high value crops and positively contribute to the economic health of the Pajaro valley. The water supply facilities constructed and operated by PVWMA and partners are designed to protect the regional water resource which fuels a nearly \$1 billion per year agro-economy. Use of the delivered water supply reduces the amount of groundwater pumped from basin, and reduces the amount of seawater intrusion into the aquifer.</li> </ul> |
| The water quality resulting from specified projects will not fall below WQOs set to protect beneficial uses.                                | <ul style="list-style-type: none"> <li>The recycled water is blended with additional sources to improve water quality. The blended water provided to growers is extensively monitored.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |

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